M.O. 590 AIR MINISTRY

METEOROLOGICAL OFFICE

THE METEOROLOGICAL MAGAZINE

Meteorological Office Centenary
1855 - 1955

VOL. 84, No. 996, JUNE 1955

Message from the Secretary of State for Air

This year marks the centenary of the State Meteorological Service. Not many scientific institutions can claim so long a history. During the past one hundred years, the Meteorological Office has built up a great tradition of service to the public, and its many notable contributions to knowledge have markedly increased the scientific and material progress of the civilized world.

Half-way through its life the development of the art of flight began greatly to increase the importance of its work. The science of meteorology has played as great a part in the history of aviation as did that of astronomy in the navigation of the seas.

Thus it was natural that in 1920 the Office should become part of the responsibilities of the Secretary of State for Air. Since that date a close and cordial association has grown up between the Meteorological Office and the Air Ministry. Throughout this period, in peace and in war, it has rendered most valuable service to the Royal Air Force and to British aviation.

While the Meteorological Office will always be closely associated with aviation, it serves many other institutions, national and private. Its name is familiar to every household in the country; its forecasts are studied daily by many millions, and are soon to be a part of the public telephone service. On the occasion of this centenary, I congratulate most warmly all members of the staff, past and present, on creating and maintaining a great tradition of public service.

FOREWORD

By THE DIRECTOR OF THE METEOROLOGICAL OFFICE

A century, although an artificial division of time, is a significant period in the history of any human organization, and centenaries afford useful opportunities to pause and look around. What we see in the record of the first hundred years of the Meteorological Office gives cause for legitimate pride. In 1855, when Admiral FitzRoy began his duties as Director, it was difficult to disentangle fact from folklore in the study of weather, and meteorology hardly existed as a science. In the years that followed, crude observation has slowly given way to exact measurement all over the globe, and our knowledge of the atmosphere now extends to regions that once were completely inaccessible. The Meteorological Office has always taken a leading part in this work. Progress in the main problem of our science, that of forecasting weather over significant periods, has not been as rapid or as sure, but this causes less surprise today than it would have in the nineteenth century. We are now in a better position to appreciate the formidable nature of the problem, perhaps the most stubborn in the whole of physical science, and a proper appreciation of the difficulties and an inkling of how they arise are an essential first step towards their resolution.

It is a far cry from the nineteenth century, with official interest in meteorology represented by a handful of staff in a small London Office, to the modern weather service with its headquarters, outstations, observatories, weather ships and research flights. Aviation and telecommunications have greatly extended the range and power of operational meteorology, but at the cost of an increasing complexity of organization. The paucity of university support for meteorology has compelled the Meteorological Office to build up its own research division, to the great profit of all concerned. Our activities now touch almost every aspect of national life, and one looks back with nostalgic wonder to the days when Shaw could write a "Manual of meteorology" that truly comprehended the science of the atmosphere in his day.

A governmental organization has little opportunity to tell its story, except on occasions like the present. Perhaps because of the nature of their work, professional meteorologists tend to be isolated from their fellow scientists. But this characteristic, now becoming much less pronounced, has had its compensations. "Once a meteorologist, always a meteorologist" may not be altogether desirable in a public service, but it has helped to create the unique spirit of fellowship that is characteristic of the Office. Of the heritage of the past, this is perhaps the most valued feature which we hope to carry into the next hundred years.

SHORT HISTORY OF THE METEOROLOGICAL OFFICE

By G. A. BULL, B.Sc.

The Meteorological Office was founded early in 1855 as the Meteorological Department of the Board of Trade and a distinguished sailor, Admiral FitzRoy, was appointed Superintendent. The title was changed to Meteorological Office in 1863.

The Department was founded, following the recommendations of an international conference held in 1853, to collect meteorological and sea-current observations for the benefit of shipping, and this work has remained an important part of the duties of the Office ever since. Observations made voluntarily by large numbers of British and foreign ships over the past hundred years have provided the basic data for the climatology of the oceans of the world.

Weather changes over an area had been studied from observations made at about the same time at a number of widely scattered stations for many years before 1860, in which year FitzRoy, encouraged by the British Association and in collaboration with Le Verrier of Paris, began the collection of observations by telegram and the organization of a forecasting service. Storm warnings were sent to ports from February 1861, and forecasts were issued to the Press from July 1861. Fuller details are given on p. 167.

FitzRoy died in 1865, and in 1866 the publication of forecasts and the issue of gale warnings were stopped on the recommendation of a Royal Society Committee which considered current scientific basic knowledge of weather inadequate for forecasting. At the end of 1866 the Office was transferred from the Board of Trade to the control of a Committee of the Royal Society, and R. H. Scott, who was to remain chief of the Office under more than one title for 33 years, was appointed Director. The Committee gave very close attention to the improvement of knowledge of the connexions between weather changes and the movements and developments of the depressions and anticyclones shown on the weather maps. Seven observatories equipped with continuously recording instruments measuring wind, pressure, temperature and rainfall were established, largely under the inspiration of Sir Francis Galton, and the records of these instruments carefully studied in relation to the movements of depressions. In the course of this work the fact that sharp changes in wind direction, pressure and temperature can occur together was recognized, but the existence of fronts extending a great distance across country was not realized. The traces for the individual elements given by these continuously recording instruments were published one above the other for immediate comparison of their variations. Following this study confidence in forecasting was regained, and the publication of forecasts was resumed in 1879. Storm warnings had been resumed soon after 1866 in response to popular request. In the first instance this was done by notifying ports of the existence of a gale observation and leaving the harbour authorities to draw their own conclusions, but by 1876 the full warning service was in operation.

The need for international standardization of methods of making and reporting observations was realized at this time, and the Director attended the first international conference for the purpose held at Leipzig in 1872. The next such conference was held in Vienna in 1873, and since then international collaboration in meteorology has been continuous with conferences at frequent intervals.

In 1877 there was an administrative change in the placing of the Office under the control of a Meteorological Council, whose members were paid by the Government and of which R. H. Scott became Secretary. Research in meteorology was largely entrusted by the Council to university and other outside workers. In this way Napier Shaw, later to become one of the most eminent of meteorologists, came into meteorological work by undertaking research on the measurement of humidity. The destruction of the Tay Bridge in a gale in 1879 led to the investigation of wind structure and the invention by W. H. Dines of an anemometer to measure wind gusts.

Dr. Napier Shaw was appointed Secretary of the Council in succession to R. H. Scott in 1900. The Meteorological Council, following the recommendations of a Treasury Committee, ceased to exist in 1905, and the Office was placed under the control of a new Committee financed by a grant-in-aid from the Treasury. Shaw became Chairman of the Committee (which included representatives of the Navy, Mercantile Marine and Ministry of Agriculture and Fisheries) and Director of the Office.

Soon after his appointment as Secretary of the Meteorological Council Shaw began to recruit highly trained physicists to the staff. The first of these was R. G. K. Lempfert whose first work was an investigation into London fogs for the London County Council. With Lempfert, Shaw investigated the air movements in depressions, a work which began with tracing the flow of air which brought dust from north Africa to give the "red rain" of February 21 and 22, 1903. In 1906 this led to the great work "Life history of surface air currents" which gave the first general picture of air movements in depressions. Shaw also worked on the relation between weather and crop yields. Another notable Office research of the first ten years of the twentieth century was E. Gold's demonstration of the close degree with which wind speed at 2,000–3,000 ft. agrees with the theoretical value calculated from the distance between the isobars.

About 1910 the meteorological needs of aviation were beginning to make themselves felt. J. S. Dines investigated wind structure for the Advisory Committee for Aeronautics, and the first outstation to give meteorological advice to aircraft pilots was opened at South Farnborough in 1912.

In the international field Shaw became in 1907 President of the International Meteorological Committee. Experience in forecasting grew rapidly under Shaw's guidance, and was embodied in his book "Forecasting weather" published in 1911. Until 1910 forecasts were limited to a period of 24 hours, but in that year "further outlooks" of weather prospects for a longer period were added whenever the forecaster thought one justified.

A major function of the Meteorological Office is to be the "public memory of the weather", that is to collect, process and publish climatological data for the British Isles, and to furnish advice for the economic life of the nation on the basis of that "memory". This side of its work was strengthened in 1912 by the taking over from the Royal Meteorological Society of the collection of the climatological observations made in England by private observers. The supervision and distribution to the Press of the observations of sunshine and weather made at Health Resorts were also undertaken in the same year. The corresponding climatological work in Scotland was not taken over from the Scottish Meteorological Society until 1920. Information was collected on world climate also,

and is used in answering many inquiries from British industrial and commercial organizations with interests overseas.

The work of the Office in general geophysics increased in 1910 by the transfer from the National Physical Laboratory of control of the observatories at Kew and Eskdalemuir, which made observations and research in terrestrial magnetism and seismology as well as meteorology. The Superintendent of the Eskdalemuir Observatory, L. F. Richardson, worked out in the next six years his revolutionary ideas on weather forecasting by numerical solution of the basic dynamical formulae of atmospheric motion, ideas that had to wait over 30 years for the invention of electronic calculating machines to bring them within the bounds of practical possibility.

The outbreak of war in 1914 led to a great increase in the work of the Office. Forecasts for the public had eventually to be stopped, but the supply of forecasts to the Services continually increased. The Office supplied trained staff to the meteorological services of the Forces in the field. Above all, the needs of aviation led to a great demand for information on the upper atmosphere.

Sir Napier Shaw was appointed in 1918 Scientific Adviser to H.M. Government on Meteorology for the duration of the war, and his administrative duties were performed by Colonel H. G. Lyons. The fruit of this appointment was the publication in 1919 of a large work on wind structure to form a volume of a planned "Manual of meteorology".

By the end of the war there were four meteorological services, the Meteorological Office and three others serving respectively the Army, Navy and Royal Air Force. The Cabinet decided in 1919 to absorb the three younger services into the Office, make the Office responsible for meeting all the meteorological needs of the nation, and attach it to the Air Ministry as the Department making most use of its services. A Meteorological Committee, composed of representatives of all Departments concerned and of the Royal Society, was established to control general policy.

An important addition to the work of giving advice based on past observations was made in 1919 when the British Rainfall Organization, which collects rainfall observations and advises water supply authorities, was taken over.

Sir Napier Shaw retired in 1920 and was succeeded by Dr. G. C. Simpson, later Sir George Simpson.

Radio first came into use in meteorology before 1914 for collecting weather reports from ships. This made it possible for ships' observations to be used by the daily forecasting service. For the British Isles the reports made voluntarily by "selected" ships have become invaluable for forecasting since they constitute almost the only source of information from the North Atlantic from which most of our weather comes. After the war the international exchange of weather reports by radio began, and by 1920 the broadcasting of forecasts for shipping in the Atlantic was in operation. The first forecast broadcast to the general public by the B.B.C. was transmitted on November 14, 1922.

During the following years the work of the Office continuously increased in volume and complexity, notably because of the needs of civil and military aviation. Meteorological offices were established at many aerodromes. The first overseas office was formed at Malta in 1922; others in Egypt and Iraq followed later. A special division met the needs from 1925 to 1930 of the

experimental work with airships. The Admiralty, however, in 1937 took over from the Office full control of the weather service for the Royal Navy.

In international work the Office was particularly prominent in the devising of new codes for transmitting weather observations to meet the increasing amount of detail needed by forecasters for the application of the new techniques of air-mass and frontal analysis. E. Gold was Chairman for 28 years of the international commission responsible for this work.

Sir George Simpson retired in 1938 and was succeeded by Dr. N. K. Johnson, later Sir Nelson Johnson.

Shortly before the outbreak of war in 1939 the method was developed of obtaining upper air observations by the radio transmission of readings of air pressure, temperature and humidity from a small instrument, the radio-sonde, carried by a free balloon. From these readings and observations of the bearings of the incoming radio signals from the balloon as it rose and drifted with the wind the upper winds also could be measured. This system enabling upper air observations to be obtained very rapidly in all weather and above cloud was to prove of the utmost importance during the war.

During the Second World War 1939–45 the demands on the Office for operational forecasts and for guidance in planning future operations were enormous. The staff gradually increased about tenfold to a maximum of some 6,000 towards the end of the war. The "target for the night" in the bomber offensive was selected by the Commander in Chief of Bomber Command in the light of the advice of his Chief Meteorological Officer following routine discussions between the senior meteorological officers at the Bomber Groups and the senior forecaster at Dunstable. Meteorological advice was vital in taking the decision to invade Normandy in 1944. Meteorological reconnaissance flights to take observations over the sea and enemy territory were organized, and the location of distant thunderstorms by observing at three stations the directions of arrival of the atmospherics produced by the storms was brought into operational use. New techniques for use in the forecasting of the much more abundant upper air information were devised.

Early in 1939 an Assistant Director was appointed to supervise research work in the Office, and in 1942 the Meteorological Research Committee of the Air Ministry was formed with an eminent scientific membership. In 1942 a Meteorological Research Flight was formed to make observations for research into such problems as ice accretion on aircraft, aircraft condensation trails, and the atmospheric water-vapour content.

Research has developed in many directions. A Deputy Director of Research and Assistant Directors of research in forecasting, instrument development, general physical meteorology and for special investigations were appointed in 1948 and an Assistant Director for climatological research in 1954. There is space for references to only a few of the problems dealt with. In forecasting research much has been done on the use of upper air observations in general forecasting, and in forecasting wind for aircraft flying at ever increasing heights. Trials of numerical forecasting with electronic calculating machinery have shown much promise. New methods of observation such as the tracking of balloons to great distances by radar for the measurement of upper winds and the use of radar for cloud investigations have been brought into use. The Meteorological Research Flight has, amongst other matters, investigated the detailed structure of the water and ice in clouds.

Since the end of the war progress in the supply of meteorological information for the life of the nation has been continuous. A great organization for civil aviation, to provide meteorological information for day-to-day operation, has been built up and a special branch has been established to study and summarize upper air temperature, humidity and wind over the whole world. Another special branch has been established to study and meet the meteorological needs of agriculture.

The international scheme for ocean weather ships, under which the United Kingdom maintains four ships staffed and equipped by the Meteorological Office at fixed stations in the North Atlantic to make both surface and upper air observations and provide navigational guidance to aircraft and air-sea rescue facilities, came into operation in 1947. Responsibility for the observation at four fixed stations is now shared with France and the Netherlands.

The B.B.C. Television Service began to show forecasts prepared by the Office in 1950; from January 1954 the television forecasts have been presented by a forecaster of the Meteorological Office.

In international meteorology the Director, Sir Nelson Johnson, was President of the International Meteorological Organization during the eventful period 1946–51 in which the Organization was transformed into the World Meteorological Organization as a specialized agency of the United Nations.

Sir Nelson Johnson retired from the Directorship in 1953 and was succeeded by Dr. O. G. Sutton, later Sir Graham Sutton.

During its century the Office has built up one of the largest meteorological libraries in the world. It has published hundreds of books and reports of researches. The *Daily Weather Report* has been published since 1869. The *Quarterly Weather Report*, *Monthly Weather Report* and *Weekly Weather Report* of summarized data must also be mentioned. Charts of marine meteorology have been produced in fulfilment of the original purpose of the Office. Of the research publications the most important are *Geophysical Memoirs*, 93 of which have been published since they were instituted in 1912. Textbooks range from the first "Barometer manual for seamen" by FitzRoy to the recent "Meteorology for aviators" and "Handbook of statistical methods in meteorology". Periodicals include the annual *British Rainfall* and the monthly *Meteorological Magazine* which came to the Office with the British Rainfall Organization in 1919, and the *Marine Observer* published quarterly since 1924.

By the end of 1954 the Office organization had grown under the Director and Principal Deputy Director to three Deputy Directorates—one for Research, one for Forecasting and Public Services, and one for Services covering the needs of the Army and military and civil aviation, twelve Divisions under Assistant Directors, and 25 Branches with a total staff of about 3,000.

FITZROY AND WEATHER FORECASTS

By SIR GEORGE SIMPSON, F.R.S.

Reprinted, by permission, from "The development of weather forecasting" in *The nineteenth century and after, London*, **101**, 1927, p. 557.

It is a remarkable fact that it was only in the middle of the nineteenth century, just when steam was about to make ocean navigation independent of the winds and largely independent of the weather, that maritime nations realized the

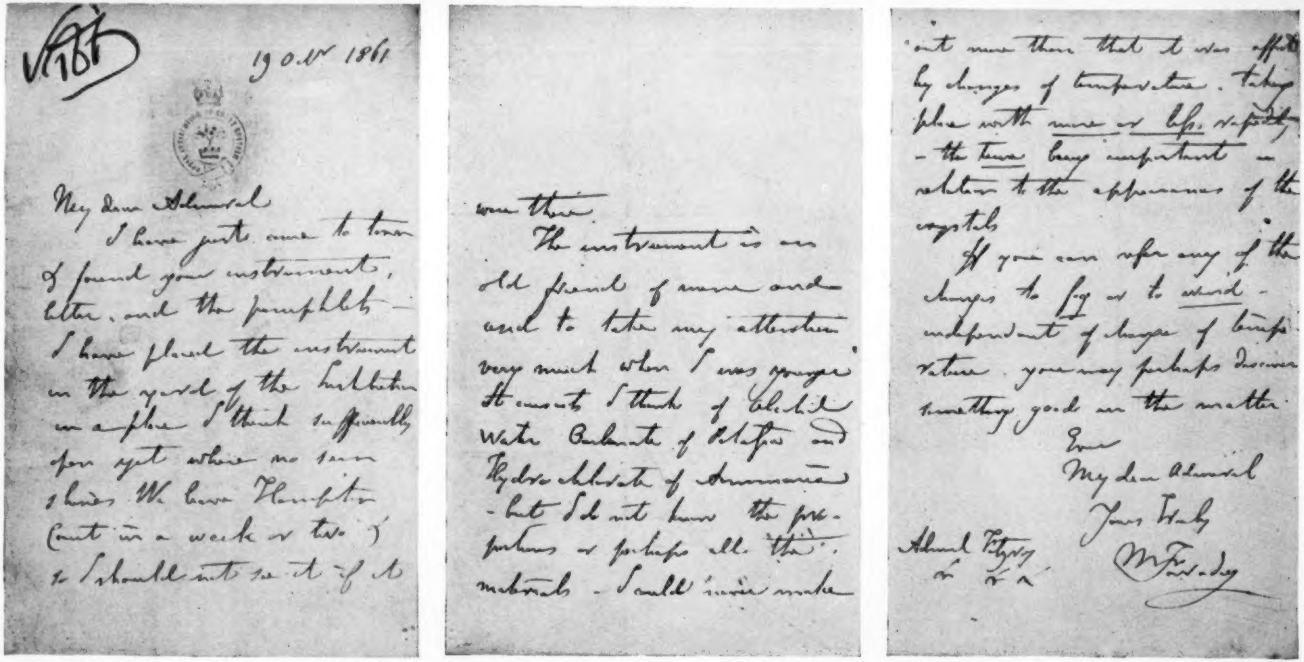
necessity of knowing the prevailing winds and ocean currents in all parts of the world in order to make safe and rapid voyages. Largely as the result of the work of Lieutenant Maury, of the United States Navy, an international conference met in Brussels in 1853 to organize an intensive study of marine meteorology in order to obtain the data so urgently required for navigation. The British Government was represented at the conference, and in the following year it was decided that the Board of Trade should establish an office for the discussion of the observations which it was proposed to make. Before doing so, however, the Board of Trade very wisely decided to consult the Royal Society "as to what are the great desiderata in meteorology", not only on the sea, but also on the land. The reply of the Royal Society is a model of what such replies should be; it stated in simple language the problems to be solved and suggested the lines along which they could be attacked.

The Meteorological Department of the Board of Trade was formed with Admiral FitzRoy, who had commanded the *Beagle* when Charles Darwin made his voyage, at its head, and the letter of the Royal Society became the instructions under which it commenced its labours. It is fascinating to a meteorologist to read what the Royal Society had to say about meteorology 73 years ago, when meteorology, as a separate science to be fostered by Government, was about to be born; but it is what the letter does not say which is the most significant. From beginning to end there is not a word about what has now come to be called weather forecasting, nor is there the slightest indication that the drafters of the letter even considered the possibility of foretelling the weather.

FitzRoy commenced his work of collecting, tabulating, and discussing observations from the sea at his new office in Parliament Street in 1854, and all went smoothly for a number of years. But in 1859 an event occurred which slowly but surely changed the whole of his attitude to meteorology, gave the English language if not a new word, at least a new phrase "weather forecast", and laid the foundations of what has become a very important branch of applied science.

In 1859 the British Association held its annual meeting at Aberdeen, and the Prince Consort was its President. The Council of the Association decided that an attempt ought to be made to make use of telegraphy to warn distant ports of the approach of storms. A resolution to this effect was communicated to the Board of Trade, who instructed Admiral FitzRoy to get into touch with the Committee of the Association dealing with the matter and to prepare a plan for an experimental trial. Two meetings were held at Buckingham Palace, when it was decided to divide Great Britain and Ireland into three "weather districts" and "to appoint a few officers (only three or four in each district) to send occasional messages according to specified readings of the instruments supplied". These messages were to be exhibited at Lloyd's and transmitted to the other co-operating stations for conspicuous posting. It is quite clear from the wording of the original resolution that no attempt to foretell the weather was contemplated; the system was simply a method by which one port could inform other ports and Lloyd's that the weather was disturbed in its neighbourhood.

Concurrently with these developments in England similar events were taking place in France, where M. Le Verrier, Senator and Director of the Imperial Observatory at Paris, had organized a daily service of telegraphic weather reports from a number of Continental stations to Paris. He wrote to Professor


19 Oct 1861

My dear Admiral

I have just come to town & found your instrument, letter, and the pamphlets — I have placed the instrument in the yard of the Institution in a place I think sufficiently open yet where no sun shines. We leave for Hampton Court in a week or two & so I should not see it if it were there.

The instrument is an old friend of mine and used to take my attention very much when I was younger. It consists I think of Alcohol Water Carbonate of Potassa and Hydrochlorate of Ammonia — but I do not know the proportions or perhaps all the materials — I could never make out more than that it was affected by changes of temperature taking place with more or less rapidity — the time being important — in relation to the appearance of the crystals.

If you can refer any of the changes to fog or to wind — independent of change of temperature, you may perhaps discover something good in the matter.

Ever
My dear Admiral
Yours truly
M. Faraday

Admiral FitzRoy
&c &c

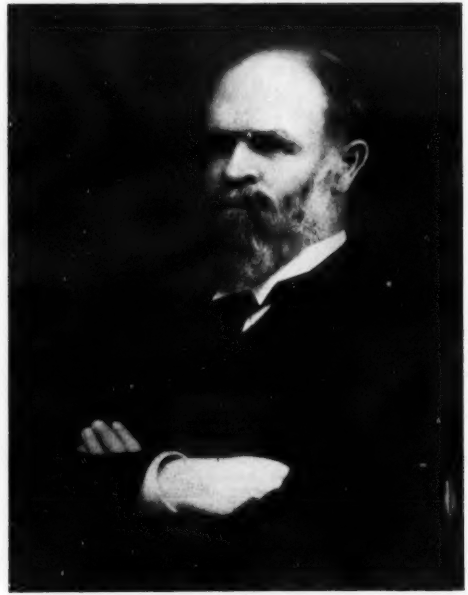
LETTER TO ADMIRAL FITZROY FROM MICHAEL FARADAY

The instrument referred to in this letter from Michael Faraday to Admiral FitzRoy is the old-fashioned "weather glass". Its method of operation remains something of a mystery !

[*To face p. 168*

To face p. 169]

VICE-ADMIRAL ROBERT FITZROY, C.B., F.R.S.,
SUPERINTENDENT OF THE METEOROLOGICAL OFFICE
1855–65



R. H. SCOTT,
DIRECTOR OF THE METEOROLOGICAL OFFICE
1866–1900

Airy, the Astronomer Royal, asking for the exchange of observations, and FitzRoy, to whom the inquiry was referred, was very willing to co-operate. To effect this exchange it was necessary for FitzRoy to obtain daily instead of occasional messages from his reporting stations, and this he arranged in the summer of 1860. Le Verrier's object, as that of the British Association and probably that of FitzRoy himself at this time, was simply to issue warnings to ports when a storm was definitely known to be in existence.

In order to inform the ports when the weather was disturbed a system of visual signals consisting of cones and drums hoisted on masts in conspicuous positions was inaugurated, and the necessary apparatus was supplied to fifty ports. In February 1861 the first storm signals were hoisted at British ports on instructions from the Meteorological Office in London.

FitzRoy was very much interested in foretelling the weather, and had already drawn up "Instructions for the use of the barometer to foretell the weather". It is, therefore, not surprising that as he contemplated each day the messages from the various parts of the country he should feel in a position to say what kind of weather was to be expected in each district, for he had only to apply the same rules to the observations which he received by telegram as he applied to those made locally to obtain equally satisfactory forecasts. Prognostications of this kind began to play a part in his storm warnings, which now became intelligent anticipations instead of mere reports of existing conditions. By August 1861 FitzRoy felt so confident of his ability to indicate the probable future weather that he decided to publish in the daily Press what he called "forecasts". The choice of this word was carefully considered, for, in his own words, "Prophecies or predictions they are not; the term forecast is strictly applicable to such an *opinion* as is the result of a scientific combination and calculation, liable to be occasionally, though rarely, marred by an unexpected 'downrush' of southerly wind, or by a rapid electrical action not yet sufficiently indicated to our extremely limited sight and feeling". The word *opinion* is in italics in the original.

This development of science in the direction of the weather prophet and maker of almanacs much disturbed men of science. Le Verrier in Paris had strongly appealed to FitzRoy to go slowly, and not to run the risk of ruining the storm-reporting service by trying to predict storms before he was in a position to do so. The feelings of Fellows of the Royal Society can be as easily imagined as described; but FitzRoy, supporting himself on the obvious public demand for his forecasts and on favourable reports of the storm warnings which he received from the ports, was not to be deflected from his path. The following statement, which he quoted to show the effect of his forecasts in an address delivered before the Royal Institution in 1862, is rather amusing: "At a recent meeting of the shareholders of the Great Western Docks at Stonehaven, Plymouth, it was stated officially that the deficiency [in revenue] is to be attributed chiefly to the absence of vessels requiring the use of the graving docks for the purpose of repairing the damages occasioned by storms and casualties at sea".

FitzRoy had the encouragement of seeing his example copied all over Europe. Le Verrier in Paris organized his storm-warning service, and even started daily forecasts, but he soon dropped the latter. Storm-warning services were established in Germany, Holland and Russia, while Denmark, Sweden, Hanover, Hamburg and Oldenburg all asked to be warned by the London Office of storms which were likely to affect them.

Weather forecasting occupied more and more of FitzRoy's time, and he took his staff off their legitimate work of collecting and discussing marine observations to help in his forecast service. Less and less money was spent on instruments and other expenses connected with the marine work, while more and more was spent on telegraphing and storm warning.

It is interesting to consider the methods employed in this early period of British weather forecasting. It must be remembered that the mapping of weather information on what are now called synoptic charts was in its extreme infancy, and although FitzRoy had himself employed such charts in a rudimentary form in his investigation of the great storm which wrecked the *Royal Charter* in 1859, he did not employ them for making his daily forecasts. I have already stated that FitzRoy had drawn up a number of rules for interpreting the readings of a barometer. They were purely empirical rules without any scientific basis except that of observation. As an example, three of his forty-seven rules may be quoted:

17. If the barometer has been about its ordinary height, say near thirty inches, at the sea-level, and is steady or rising, while the thermometer falls, and dampness becomes less, north-westerly, northerly or north-easterly wind, or less wind, less rain or snow, may be expected.

18. On the contrary—if a fall takes place, with a rising thermometer and increased dampness, wind and rain may be expected from the south-eastward, southward, or south-westward.

19. In winter, a fall, with low thermometer, foretells snow.

Empirical as FitzRoy's rules are, they are wonderfully correct, and there is hardly a single one for which a scientific reason cannot now be given, although the reason was entirely unknown to FitzRoy.

Each morning reports were received by telegram from sixteen stations in the United Kingdom and from four stations on the Continent, the latter being received from Paris in exchange for the messages sent to Le Verrier. A list of the observations was made, and then by simple inspection of these returns forecasts for different parts of the country were prepared. No notes or calculations upon paper were made; the operation was conducted mentally and occupied about half an hour. As soon as the forecasts were made they were sent to the newspapers, and if storms were foretold notice was sent by telegraph to the ports to hoist the storm signals.

In April 1865 Admiral FitzRoy died, and the Board of Trade, who had evidently become uneasy regarding the changes in the Meteorological Office, considered this a good opportunity to have the whole position investigated. They again sought the help of the Royal Society, and a small committee, with Mr. Francis Galton as chairman, was set up for the purpose. The committee was shocked at the way in which the programme laid down by the Royal Society in 1855 had been neglected, and at the great accumulation of marine observations which had received little or no attention in the Office. We are not, however, concerned here with this aspect of the committee's report, but the following question and answer may appropriately be quoted:

Question 4. Assuming that the system of weather telegraphy is to be continued, can the mode of carrying it on and publishing the results be improved?

Answer. The system of weather telegraphy and of foretelling weather is not in a satisfactory state. It is not carried on by precise rules; and has not been established by a sufficient induction from facts. The storm warnings have, however, been to a certain degree successful, and are highly prized. We think that the daily forecasts ought to be discontinued, and that an endeavour should be made to improve the storm warnings, to define the principles on which they are issued, and to test those principles by accurate observations.

On receiving the report of the committee the Board of Trade realized the difficulty of a Government Department controlling a purely scientific service, and they proposed to the Royal Society that the latter should appoint a committee to take over the management of a reorganized Meteorological Office. The Royal Society agreed to this proposal only on the condition that storm warnings and weather forecasts should be dropped. The Board of Trade accepted this condition, and at the end of 1866 the management of the Meteorological Office passed into the hands of a strong committee appointed by the Royal Society.

Thus ended in apparent failure the first attempt to issue official weather forecasts in this country; but the reputation of the great admiral, the first official meteorologist, in no wise suffers. He was a true pioneer, and if he had any fault it was the praiseworthy one of refusing to be deflected from his path by the advice of more timorous men, but facing his difficulties and frequent failures without losing confidence in achieving the great task which he had set before himself. And one wonders whether his failures were so real as made out by the committee. FitzRoy knew more about the weather and the sequence of its changes than any man then living; therefore, when fortified by his daily reports, he could tell the public more than they knew, or could possibly know, of what weather to expect. Surely this was something gained and was better than passive ignorance. But the committee realized this fully, and I will let them speak on FitzRoy's behalf by quoting the last paragraph of their report:

> We feel moreover that we should be doing great injustice to ourselves if we were to allow it to be supposed that we under-value either what the late Admiral FitzRoy attempted or what he effected. To his zeal and perseverance is due the credit of establishing a system of storm warnings which is already highly prized by the seafaring class; and, if a more scientific method should hereafter succeed in placing the practice of foretelling weather on a clear and certain basis, it will not be forgotten that it was Admiral FitzRoy who gave the first impulse to this branch of inquiry, who induced men of science and the public to take interest in it and who sacrificed his life to the cause.

The Meteorological Office came under its new management at the end of 1866. At once a circular was issued suspending the storm warnings, and the issue of forecasts was discontinued. Immediately there was a great popular outcry. Memorials praying for the restitution of the storm warnings were forwarded from several ports, and questions were repeatedly brought before Parliament. The Board of Trade felt their hand forced, and they requested the committee "to give some intelligence of storms in such a manner as they might think fit". The committee had to bow to the popular demand, and they agreed to issue a communication as soon as a storm or a serious atmospheric disturbance *existed* on some part of our coasts. This was simply a return to the original idea of issuing warnings which were only statements of fact and not of opinion. Still public opinion was not satisfied, and the demand for forecasts continued. The British Association at their meeting at Dundee in 1867 passed a very strong resolution praying for the restitution of the FitzRoy system. To all requests for forecasts the committee turned a deaf ear.

The Meteorological Office, however, did not let the matter rest in this *non possum* state. The daily messages from the telegraphic reporting stations were continued, and a daily weather report was published containing the observations and a general statement of the weather over the British Isles, but no forecast. Each day the observations as they were received were plotted on charts, and these were carefully studied. In the meantime Buys Ballot had enunciated the

law which goes by his name connecting wind force and direction with the distribution of barometric pressure. In this way the study of the weather by means of synoptic charts was inaugurated, and it was soon found that the weather map was a more powerful aid to systematizing and interpreting weather changes than FitzRoy's rules. It was found that the weather bore a very close relationship to the type of isobars shown on the maps. Barometric depressions as the cause of cyclonic storms had long been known; now the areas of high pressure, to which Galton gave the name of anticyclones, were recognized also as regions of very characteristic weather.

As this improved knowledge slowly accumulated the temptation to use it became irresistible. Although the very idea of issuing forecasts remained anathema to the committee, the Director of the Office, to whom "the issue of storm warnings, etc., has necessarily been confided by the committee", slowly and cautiously introduced the element of anticipation into the warnings, and from a report which he made to the committee in 1876 it is clear that he was then making great use of his daily synoptic charts in determining the development and future movement of storms. Thus again the Meteorological Office started down the slippery slope of forecasting which FitzRoy had so disastrously trodden and in exactly the same way, except that now weather maps replaced verbal rules.

In 1877 another change was made in the management of the Office. The appointment of a committee by the Royal Society to manage the Meteorological Office had always been considered to be a provisional arrangement, and at first it was suggested that it should be appointed for three years only; but, as a matter of fact, it retained control until 1877, when, owing to difficulty with the Scottish Meteorological Society, it was decided to replace the voluntary committee by a paid council. This change made no difference at first in the attitude of the Meteorological Office towards the issue of forecasts; but in 1879 the council decided that the knowledge of the sequence of weather had been so much extended by the study of synoptic charts that the issue of forecasts, which had now been discontinued for thirteen years, might be recommenced.

The complaint of the committee which investigated the work of the Meteorological Office on the death of Admiral FitzRoy had been that the system of forecasting employed by FitzRoy "is not carried on by precise rules: and has not been established by a sufficient induction from facts". To forestall a similar complaint against the new series of forecasts the council asked the Hon. Ralph Abercromby, an experienced sailor, a keen observer and an acute meteorologist, to formulate the rules employed in the official forecasts. The result was a small book published by the council under the title "Principles of forecasting by means of weather charts". It throws a sidelight on the attitude of the council to forecasting at this time that they should ask an outsider to prepare an account of the methods used in the Office, and even then that the author should state in his preface:

> It must be understood that the Meteorological Council, although authorizing the publication of the work [he had already said that it had been undertaken at the request of the council], accept no responsibility for the opinions it contains, which are therefore to be regarded as those of the author alone.

In 1880 the Meteorological Office had reached the stage at which modern methods may be said to have commenced; a copious supply of observations was received daily by telegram from fifty well spread stations in the United Kingdom

and on the Continent; synoptic charts were drawn and a method with some claim to being scientific, although quite as empirical as FitzRoy's, was used to prepare the forecasts. All future advances have been developments along these lines making use of wireless, aeroplanes, radar and television, all undreamed of by FitzRoy, leading to the great organization described on other pages.

THE METEOROLOGICAL OFFICE AND THE FIRST WORLD WAR

By E. GOLD, D.S.O., F.R.S.

The first outstanding impact of meteorology on military operations in the war arose from the bombing of east coast towns by Zeppelins (airships) in the spring of 1915. In those days there was no observation of upper winds in, or above, a cloud layer, and very little on other occasions. The only effective guide to the upper wind was the geostrophic wind (gradient wind as it was then called). It was clear as daylight from the synoptic charts, even reduced as they were, that the Zeppelins had been carried north and east of their target, London, by a SW. geostrophic wind of which they had no knowledge prior to, or during, their passage across the North Sea. When the Director, Dr. Shaw, brought this to the notice of the appropriate authorities, they began to think more seriously of meteorology as a factor in war.

(It was a later disaster to Zeppelins, on October 19, 1917, through failure to allow for the effect of a warm air mass to the west in turning a weak southerly wind at low levels into a strong northerly wind at very great heights, that was the occasion of my origination of the term "thermal wind".)

Almost simultaneously with the 1915 Zeppelin event, occurred the German gas attack near Ypres, in violation of the convention to which Germany was a party, prohibiting the use of gas in war. At that time a gas attack could be made only with a wind which would drift the gas released from cylinders in the direction of the enemy and do so without dispersing it too rapidly to let it reach the enemy in effective concentration. Thus the decision to retaliate naturally brought meteorology directly into the field of British offensive military operations, and the need for a meteorological service with the Army in France, obvious to the meteorologists, became clear also to the soldiers.

After the outbreak of war, July 28–August 4, 1914, the meteorological information received was limited to that from the British Isles and France, and some reports from Spain and, later, from Scandinavian countries. At first forecasts continued in the Press and the *Daily Weather Report* was issued, though subsequently issue to the public was only after a fortnight's interval, and publication of forecasts in the Press was stopped. Meteorological information for the British Expeditionary Force in France was supplied direct from the Meteorological Office in London (without any adequate reports of conditions in the area of operations in France). Now a detachment—or rather a couple of officers—was to be sent to France. They were described as the "Meteorological Field Service", which in fact they grew into, though the name was changed within a few months to Meteorological Section R.E. and abridged generally to "Meteor".

The general organization of the military meteorological services was in the charge of Maj. H. G. Lyons, R.E. acting for the Director of the Meteorological Office. The staff of the Field Service for France consisted of a meteorologist

of the rank of Captain (E. Gold), and a professional assistant of the rank of Lieutenant (A. E. M. Geddes), the latter "for upper wind observations", commissioned in the General Infantry, and stationed at General Headquarters. Technical or clerical assistance was to be provided by the Army in France. There were to be reserve officers at "Home" ready to exchange duty with the staff on Field Service.

Briefly the major functions of the service as then visualized by the military authorities were to provide: (*a*) meteorological information for offensive gas operations and defence against enemy gas operations (this was primarily existing and expected direction and strength of the surface wind); (*b*) forecasts for "battles", wind, weather, cloud and, later, visibility; (*c*) meteorological information for the Royal Flying Corps, mainly cloud and wind at flying heights, fog and line squalls; (*d*) the regular issue of general weather forecasts for use in the varied work of the Army; and, later, (*e*) the supply of information (at short intervals of time and quickly enough for it to be applicable at the time of its receipt by the gunners) of the wind and temperature at the different levels up to the vertices of the trajectories of shells fired from guns and howitzers. An account of this last function, one of the most important parts of the work of the section, has been given in an article in the *Army Quarterly* for October 1943. It introduced into practice the "equivalent constant wind" and "equivalent temperature".

Almost simultaneously with the establishment of the Meteorological Field Service, the Gas Adviser in France, Lt-Col. C. E. Foulkes, arranged for one Meteorological Officer, commissioned R.E., to be included in the establishment of each of the two "Special Companies" which were being formed for offensive gas operations. It appeared to me essential to have a single meteorological service under one control. I discussed this with the Gas Adviser who agreed and the two officers joined the staff at St. Omer (G.H.Q.) and assisted in the preparations for the first gas attack.

The basic meteorological information which furnished our "stock-in-trade" consisted of 5 telegrams daily from London, giving forecasts and coded reports in five-figure groups, 20 groups at 2 a.m., 100 groups at 9.30 a.m. and 80 groups at 7.30 p.m. It was at once apparent that meteorological observers were required to make observations in the British Army area, especially near the front about 50 miles from north to south but in process of extension to about double that distance. None of the staff of the Office could be spared, but four men of meteorological experience already in the Army were transferred, namely J. Durward (of the 4th Gordon Highlanders, the first to report on June 16 and for some time our only assistant), R. Pyser, L. G. H. Lee, and F. J. Parsons. Capt. C. J. P. Cave, who had been commissioned as the reserve Officer, came out on July 7, and undertook the instruction and posting of the local observers of whom 12 were obtained from the Artists Rifles.

The Meteorological Service grew naturally as the Army gradually realized its value. After the battles of Loos and Hulluch in September and October 1915, the Service, which then had no recognized place in the general Army organization, was formally established as "The Meteorological Section of the Royal Engineers" with a Commandant (Major), Captain, 6 Subalterns, 2 Sergeants, 16 Corporals, 1 clerk and 6 batmen; a car for the Commandant, 3 motor cycles for the subalterns and 2 bicycles for the observers not located close to their observation posts. From time to time this establishment was increased;

in 1918 it was 16 Officers and 82 other ranks, with 5 Officers and 20 other ranks attached from Sound Ranging solely for meteorological duties. A further increase to 28 Officers and 187 other ranks was agreed by the Army later in 1918.

The Service began as a purely G.H.Q. establishment, but already by the end of 1915 it had been agreed that there should be a Meteorological Officer at each of the, then three, armies. These started in 1915 as Lieutenants, under a later establishment they became Captains, and provision was made in the final establishment for them to be Majors but the Armistice came and the promotion never took place. The Commandant was promoted Major at the end of 1915 and Lieutenant-Colonel in 1918. Sanction for the latter promotion, agreed by the Commander in Chief in France, was delayed by the War Office until the promotion of Maj. H. G. Lyons had been effected. It was largely due to this delay that the Officers did not get the promotion to Major which they had so long deserved. The section in France became, after March 31, 1919, the Meteorological Section of the British Army of the Rhine under the command of Maj. A. H. R. Goldie.

In December 1917 a detachment was sent to Italy where it remained until the beginning of 1919. It was initially under the command of Capt. A. H. R. Goldie, who wrote "It is worthy of remark that after some initial difficulties the British part of the weather charts was usually completed first both in our own Office and in that of the Italian Aerological Section. It is also noteworthy that the Italian Aerological Section could receive the French data more quickly *via* the British Sections in France and Italy than direct from Paris or *via* the French Section in Italy. These facts impressed the Italian Section with a great respect for British meteorological organization and British telegraphy."

In 1918 a detachment from the Section, under the command of Capt. D. Brunt, went to the Independent Air Force, whose Headquarters were near Nancy, and there gave meteorological advice vital to their operations and greatly appreciated by Gen. Trenchard and his staff.

The use of meteorological information for the offensive use of gas in connexion with the Battle of Loos in September and Hulluch in October 1915, when cylinders discharged from the trenches were used, and later for attacks in which "projectors" were used, is outlined in the article in the *Army Quarterly* for October 1943. The brilliant use, by Capt. Bispham and Capt. Lamb, of katabatic winds, which provoked the enemy's comment that the British used gas when the meteorological conditions didn't justify it, ought to be specially mentioned.

After the Battle of Loos in the winter of 1915–16 when it was expected that the enemy would make further gas attacks, meteorological observations were communicated direct to Divisions whenever the wind was from a quarter favourable for enemy gas attacks, to enable the gas alert to be instituted when it was necessary and only when it was necessary.

It was in connexion with the information required for the use of or defence against gas that the airmeter was introduced to measure the wind at about 4 or 5 ft. above ground level in an open situation. As a result of examining a number of airmeter observations in which the values of speed at 2-min. intervals and the values of direction at intervening 1-min. intervals over a period of about 20 min. were measured, Capt. Goldie discovered the relation $v/V = \sin \frac{1}{2}A$ where v is the range of values of speed, V is the mean speed, and A is the angle through which the direction varies.

The main information required by the R.F.C. was naturally forecasts of weather and cloud, including cloud height, and visibility. When night flying developed, the upper wind became of great importance. At that time, it was extremely difficult to get observations of upper wind at night and trials were made with electric lamps and with flares but they were not very successful. Sir Napier Shaw sent out some Chinese lanterns but the candles in them blew out when the balloon was released. In November 1916, Lt Bispham tried covering the top of the lantern with the thin metal lid of a cigarette tin and got an ascent to over 3,000 ft. The method proved very successful, and the balloons were watched to as great a height at night as in the day-time. The ingenuity of N.C.O's at the pilot-balloon stations soon enabled them to devise a lantern which could be made, and was made, at the stations.

In connexion with the observations by pilot balloons, the computations were originally done by slide-rule after the ascent had been completed, and the computations took nearly an hour after an ascent lasting half an hour. At the beginning of 1916, with the assistance of Lt Entwistle and Corp. Durward, the procedure was simplified, and instructions prepared which shortened the time for computation very substantially; and after observers had become accustomed to the new method, they were able to do the computations during the ascent of the balloon and complete it within 2 min. of the end of the ascent. This was of outstanding value not only in connexion with the information about upper wind required by the R.F.C. but probably, even more important, in accelerating the issue of information for the Artillery.

A kite balloon was also obtained for meteorological observations. It soon appeared that the observations of wind from the kite balloon were affected by the balloon itself, when the anemometer was placed in its usual position on a trapeze above the basket. These speeds were about 40 per cent. higher than those measured by an anemometer 20 ft. below the balloon and 60 per cent. higher than the speeds obtained by observation of free balloons.

The account of the meteorological arrangements for the Battle of Loos has been given in some detail in the *Army Quarterly* for October 1943. The same article contains a summary of the relevant meteorological facts for the other main battles of the war. The outstanding importance of the success of the forecasts prior to and for Loos was that they established a degree of confidence in the meteorological service which enabled the service to develop and secure a comparatively high degree of use of meteorological information during the war.

The recognition of the importance of visibility was slow in development. It was however emphasized in the preparation for the battle of Cambrai, but the strategic use of predictable natural fog was never adequately examined or applied.

Early in 1918 meteorological aeroplanes were allotted by the R.F.C. and initially were flown by Lt G. Marden and Lt E. H. Sessions. Later, in May 1918, Capt. C. K. M. Douglas became available for meteorological work, and he and Lt Sessions provided not only observations of temperature and humidity up to a height of about 14,000 ft. but also a very illuminating series of cloud photographs from aircraft. The upper air observations of temperature found their most regular application in the preparation of the reports for the Artillery. Naturally, they also proved useful as aids to forecasts. Perhaps the most notable example was at the beginning of the final offensive of the war in August 1918. Gen. Rawlinson, who was commanding the army which initiated the final

series of attacks, consulted me about the weather and I was fortified in my assurance to him that appreciable rain was not to be expected, by the fact which I quoted to him "that the temperature in the upper air was high and the atmosphere therefore stable" (a reason to be used with discretion, in the light of the rest of the synoptic situation).

From the outset copies of the synoptic chart were prepared, at first in very limited numbers by hand, and distributed both at G.H.Q. and A.H.Q. Later, on the instigation of Capt. Goldie, "clay copiers" were introduced which permitted the preparation of a complete local *Daily Weather Report* and a wider distribution, and a new departure, colouring red the isobars of pressure above normal.

It became clear during the war in France that the standard meteorological observations and the code for reporting them were quite inadequate to provide the basis for the preparation of the forecasts required in military operations. Consequently a new code was prepared and used for reports from the stations of "Meteor". It included in addition to the information in the standard code (*a*) visibility by one figure on a logical scale of distances, which is one of geometrical and not of arithmetical progression, (*b*) the form and amount of low cloud and of medium or high cloud, (*c*) the relative humidity, (*d*) present weather by two figures, (*e*) past weather by two pairs of figures to permit of reporting a sequence, (*f*) rainfall twice daily, and (*g*) maximum day temperature and minimum night temperature.

The code was discussed at a meeting with French meteorologists in London in July 1918, and in the spring of 1919 it was included, substantially without change, in the International Convention for Air Navigation, with the concurrence of the United States meteorological representative at the Peace Conference. The code formed the basis of the codes subsequently adopted by the International Meteorological Organization and was used generally in the interwar years and during the Second World War. The only major change was in the reduction of the scale for past weather to a single-figure scale; this deprived meteorologists of information of substantial assistance.

Another development was the inclusion in the regular forecasts of the expected day and night temperatures. Not until after the lapse of 30 years was it possible to persuade the Meteorological Office to include this information in its regular forecasts.

It would be unpardonable to omit from this account a grateful acknowledgment of all that the Meteorological Office in London did to facilitate the work of the Section in France. First and foremost by the ready, regular and prompt despatch of the collective messages; then by the preparation and issue of numerous forms and blank charts, both general charts and special detailed contour charts of the Army area for plotting local observations; and for the provision of instruments both standard and novel such as the swinging plate anemometer and the accessories for the field use of the airmeter; and improved theodolites and balloons more in number than the sands of the sea.

This article has dealt mainly with the initiation by the Office of the Meteorological Service with the armies in France and the development there in the application of meteorology in the war by land and in the air. The work of the Office for the Navy and the development of the Naval Meteorological Service would require a separate article for a description at all adequate of it.

The same remark applies to the Meteorological Service with the Expedition to the Dardanelles and subsequently to Salonika. This was under the command of Capt. E. M. Wedderburn, who became the leading expert on the problem of the meteorological corrections to gunnery and the refinements necessary for the proper computation of the "equivalent constant wind".

Similarly only brief mention can be made of the detachment which went to north Russia in 1919, officered by Capt. W. H. Pick and Lt M. A. Giblett. Out of this came Pick's *Professional Note* on upper wind and the discovery that at Murmansk the wind in the first 2,000 ft. often backed continuously from the surface wind, when the latter was NE., contrary to the usual veering of the upper wind.

THE METEOROLOGICAL OFFICE AND THE SECOND WORLD WAR

By J. M. STAGG, D.Sc.

Weather has been a decisive factor in the fate of famous battles through the centuries. For all we know some of the commanders concerned may have consulted the meteorological oracles before engaging their forces; but when the history of meteorology comes to be written it will surely be recorded that it was not until 1915 that a commander decided to commit his troops on the basis of a scientifically prepared weather forecast. By the outbreak of the second world war meteorological advice for military operations on land and sea and in the air had become so much appreciated that the meteorological officer was brought on to the commander's staff at the planning stage, and he could influence decisions on even the largest scale of operations. History will also record that it was more than a coincidence that two of the major advances in weather forecasting were related to those two wars: the development of the idea of fronts and the introduction of three-dimensional analysis as a regular and indispensable procedure in the preparation of forecasts.

To the Director of the Meteorological Office, who in the years before 1939 had to make many decisions about the shape of the organization that would be needed in war time, it was encouraging to know that the fighting services had come to value the help which meteorology could give them. Many of the pre-war decisions were important and far reaching and stood the test of the whole war basically unchanged; a new meteorological organization for the R.A.F. commands and a teleprinter network for rapid collection and distribution of information were two examples. But no one could have foreseen the problems of recruitment and training of a staff that grew from 750 in March 1939 to nearly 6,800 in 1945, or the difficulties created by this rapid dilution of experience in working with a still largely empirical science—difficulties that were certainly not diminished by the range of operational activities on which the Meteorological Office was called upon to advise or by the necessity for deploying the available staff in small and widely dispersed units. Nor was it possible in 1939 to anticipate the radical changes in forecasting practice that were to result from the experiments then in progress at Larkhill on the measurement of high-level winds by the use of radio-triangulation methods. Before long these measurements were developed to a state that allowed similar stations to be set up elsewhere in the British Isles, and much improved information about the atmosphere in all conditions of cloud and visibility became regularly available for the first time.

The first actual moves towards a war-time footing were carried out quietly and smoothly before war was declared. In the latter part of August 1939 the main forecasting centre moved from London to a temporary home in Birmingham, and a few days later those forecasters and assistants who had been selected to meet the first urgent requirements of the Royal Air Force were redistributed to take up their war-time stations at new airfields. On September 1 full security restrictions were imposed on the use of meteorological information; from then until May 1945 all broadcasts of synoptic data in clear were stopped and many limits were set to the issue of weather news to the public. An advance party of meteorological detachments for the expeditionary force arrived in France on September 3, and about the same time the machinery for recruiting and training new staff was set going. The first batch of 40 volunteer officers from other professions were mobilized into the meteorological branch of the R.A.F.V.R., and by the middle of the month those volunteers, along with newly entered civilians who had been recruited into special war-time grades, formed the earliest of what was to be a long series of classes in the Meteorological Office Training School.

With the heavy responsibility laid on the Royal Air Force from the outset it was natural that the biggest demands on the resources of the Office should be for observing and forecasting units to keep pace with the rapidly increasing scale of operations conducted from airfields in the United Kingdom. At first those units were manned on an emergency basis, big enough to maintain a round-the-clock service for only a limited time; they soon needed strengthening. But as the number of bases needed for R.A.F. operational wings and squadrons increased the attachment of even one additional forecaster or one additional assistant to each airfield throughout a command used up the greater part of the output from the training school and left little for coping with the new calls for meteorological assistance that soon began to come in. These ranged from complete forecasting sections for new group headquarters of Coastal and Fighter Command and for reinforcements for the sections in France and for forecasting facilities to deal with oversea delivery flights—from these to advisers for smoke-screen operations and many other specialized tasks.

The diversity of operational tasks for which meteorological advice and information were sought at this time probably perplexed the Director as much as did the number and volume of the demands. For if the new kinds of duty were to be efficiently performed he had to ensure that some of the best and most experienced staff should form the nucleus of each new unit, and that required frequent redistribution of the available forecasters and assistants. To the war-time entrants who perhaps did not appreciate the need for, much less relish these frequent postings, life as a member of the Meteorological Office staff in those early years must have seemed an irksome business; but the careful dilution of experience was essential if the service was to carry out its obligations, and it certainly paid good dividends when the time came to set up self-contained organizations for operating abroad with combined land and air forces.

It is perhaps relevant while dealing with staff matters to refer to another aspect of life in the Meteorological Office that puzzled many in those early years: the question whether or not staff should be in uniform. The idea at first was that civilian staff should serve the home commands of the R.A.F., particularly Bomber, Coastal and Fighter (where indeed the heaviest burden at that stage fell and where most experience was needed) while the members of

the Meteorological Branch of the R.A.F. Volunteer Reserve would work in theatres of operation oversea. As the reservist strength at the outbreak of war was only 7 officers and 22 other ranks this policy had the consequence that after the expeditionary force to the Continent was manned future units sent abroad would be composed mainly of inexperienced war-time entrants. When other defects became evident, such as the difficulty of interchanging staff between home and oversea stations and the need for ensuring confidential relations between the R.A.F. and Army staffs of home-based (though none the less operational) commands and their civilian meteorological advisers, the whole matter was reviewed. In 1942 all forecasters serving abroad, except those in a few clearly non-operational theatres, became R.A.F. officers with a special kind of commission, and early in the following year most of the forecasting staff attached to operational commands at home were mobilized in the R.A.F.V.R. together with those assistants who had not been directly recruited. It may be noted here that, both as officers and airwomen of the Women's Royal Air Force and as civilians, women took a substantial and honourable share in a wide range of meteorological duties. They were debarred only from service overseas and from forecasting duties at operational stations, though even there a relaxation was made in the latter half of the war when they took equal part with their male colleagues in the briefing of aircrews at operational training airfields.

Meanwhile the Army's needs were not overlooked. The main forecasting section which had accompanied the advanced air striking force to France at the outbreak of hostilities was designed to serve the headquarters of the Army as well as the R.A.F., and many of its ancillary units were trained to work closely with the artillery and with survey regiments. In the next phase of the war when the Army was being re-organized after Dunkirk opportunity was taken to provide meteorological advice at more levels than had been possible with the expeditionary force. A forecasting section was formed at G.H.Q. Home Forces with liaison officers at the headquarters of commands, corps and divisions, and mobile units were established for specialized duties. As the pattern of the new Army crystallized, and more especially as the form of air co-operation with the Army took shape, these arrangements were gradually modified, the main meteorological sections being attached to progressively higher echelons so as to serve a dual role at the joint Army/R.A.F. headquarters. This became the accepted pattern throughout the later stages of the war and was carried into the arrangements for "Torch" and the subsequent campaigns in north Africa and Italy, for the British air and land forces in "Overlord" and its follow-up into Germany, and for the organization based on India and Ceylon.

While this kind of composite organization was being evolved to provide forecasts and weather information to the field forces, sections elsewhere had been attached to the schools for the training of airborne troops; and as appreciation of the advice which meteorology could give to parachute and glider operations gradually accumulated, the separate sections were increased and were merged into a single training and operational organization for airborne forces. This organization became part of No. 38 Wing (later Group), and played an invaluable part in the Normandy landings and the subsequent campaign.

The story of the activities of the Middle East meteorological service from 1940 to 1945 is a history in itself. On the entry of Italy into the war the various services based on the Canal Zone expanded rapidly, and the chief meteorological officer in that area soon found himself in control of observing and forecasting

detachments spread over the Western Desert, Iraq, Persia, Palestine, Trans-jordan, Aden, Syria and Cyprus, and at the same time he had to collaborate closely with the sister services of British East Africa and South Africa. Every major event throughout the area had its meteorological counterpart. Meteorological Office staff were with the forces operating in Abyssinia, in Iraq during the rebellion, in Greece, and in Crete, and throughout the long and anxious operations in the Western Desert which ultimately led to the invasion of Sicily and Italy. There the staff of the meteorological service based in the Middle East linked with the organization from the United Kingdom which had served the British forces in the "Torch" landings in Algeria and in the campaign there and in Tunisia.

During those difficult years in the Mediterranean area Office staff of the distributive and forecasting stations at Gibraltar and Malta continued to serve the air and sea routes that kept the United Kingdom in touch with the Middle East and north Africa. But as these became more difficult to maintain just when greater volumes of traffic had to be handled, the other air re-inforcing route which had been established from west Africa into the Middle East came more into prominence; and to serve this trans-African lifeline forecasting stations manned by staff from the Meteorological Office were set up along the chain of airfields that stretched from the main bases in west Africa, through Nigeria into Sudan and Egypt. Meanwhile on the other (eastern) side of Africa and at Aden the commitments of the Meteorological Office had been steadily stepped up to serve the air force units operating there and in the western Indian Ocean; the interdependent service provided jointly by the Meteorological Office and the British East African meteorological service was further strengthened in 1943 when the British East African service came under control of the London Office.

Farther east in India a completely new organization working in close harmony with the Indian Meteorological Service was formed to provide for the needs of British and allied forces in the war against Japan. Under a chief meteorological officer with his headquarters first at Delhi and later in Ceylon this new service grew in the years 1943–45 into a large and complex organization with responsibilities that extended into Burma and throughout the whole area under the supreme allied commander for south-east Asia.

In the meantime important developments had also been taking place nearer home. The Central Forecasting Office had moved from Birmingham in February 1940 to its permanent war-time home near Dunstable, there to become widely known as ETA, the code name for the evacuation site it occupied. During its short stay in the Midlands the experiments in progress at Larkhill just before the war on the measurement of high-level winds by radio began to bear fruit. The first regular issue to outstations of isobaric charts for the 2 Km. and 5 Km. levels began in January 1940, to be superseded a year later by height contours of the 750, 500 and 250 mb. surfaces. Throughout the war years ETA steadily improved its position as the hub of the British synoptic service, both as the collecting and distributive centre of observations and as the guide and adviser behind the scenes of the great family of forecasting stations attached to British and allied forces. As more upper air data became regularly available and covered an increasingly wider area, a new section was set up within ETA specially to deal with high-level analysis, and in its role as adviser in forecast matters both for the operational forces and for other essential services many important and novel tasks were added to ETA's schedule of responsibilities.

In this work and more especially perhaps for the guidance provided in co-operation with the forecasting sections at all levels in Coastal, Bomber and Ferry (later to become Transport) Commands, the weather information transmitted back to ETA by the meteorological reconnaissance crews on their long and often dangerous flights to the north, south, east and west of the British Isles was invaluable.

If space had permitted a whole section of this article should have been devoted to Meteorological Office participation in the decisions which led up to the allied landings in Normandy, and another to the activities of the large organization, modelled in the light of all the earlier experience of meteorological co-operation with land and air forces in the field, which accompanied the Second Tactical Air Force and 21 Army Group to France, and served them in their campaigns through Belgium and Holland and across the Rhine into Germany. In another category though hardly less indispensable was the work of the forecasters and assistants who found themselves manning isolated units in the Faeroes, in Iceland, in the Azores and in the West Indies, and in the operational training schools in Canada and South Africa. In many if not actually most of those enterprises meteorological staff of other services were more or less intimately involved, either in friendly co-operation as in the case of our own Naval Meteorological Service and the meteorological services of Canada, South Africa, France, Portugal, Iceland and of course the Weather Service of the United States Army Air Force both at home and in other theatres, or by actively becoming war-time members of the Meteorological Office as did many meteorologists from Belgium, Czechoslovakia, France, Norway, Poland and other friendly countries. Both as services and as individuals they gave help that was deeply appreciated.

Even if it had been possible to describe all these operational activities, a section would still remain to be written about the less spectacular though scarcely less valuable work of maintaining the climatological service and adapting it to meet war-time needs, and the heavy task of providing so many new units and stations often at short notice with their equipment and instruments. During the war new instruments were designed, developed and came into operational use, among them the Kew-pattern radio-sonde and the Dobson-Brewer frost-point hygrometer; and from radio direction-finding with a triangle of stations the measurement of high-level winds in all weather conditions was transformed by application of radar into a single-station procedure. These and other developments brought to light for the first time many new phenomena of the higher troposphere and stratosphere and the search for explanations led to the opening up of new investigational ground. This and the creation in 1941 of the Meteorological Research Committee began a new era of fruitful research in the Office.

It has been regretfully necessary in this brief story to suppress the human aspects of all these activities and particularly to omit reference to individual members of the staff. But exception must be made of two officers whose contributions to the conduct of the British meteorological services in those war years were inestimable, the Director, the late Sir Nelson Johnson, and his deputy, Mr. E. Gold. To the Director from first to last fell the responsibility for planning and deciding on the most effective use of his resources in staff and equipment, spread throughout every theatre in which British forces operated—from the Arctic Circle to Capetown, from Canada and the United States eastward

through the length and breadth of Africa, western Europe, the Mediterranean, and the Middle East to India and Burma. The development and control of every aspect of the synoptic forecasting service was in Mr. Gold's hands, and to it he made contributions which are now internationally recognized as corner stones in forecasting practice; among them he brought system and order into the distribution of information and he introduced the prebaratic and prontour charts. Under Sir Nelson Johnson and Mr. Gold the staff of the Meteorological Office during the war years made to the nation's effort a contribution of which any scientific organization could be proud, and one which will always stand out as the finest in the first hundred years of its history.

THE METEOROLOGICAL OFFICE FACES THE FUTURE

Scientific Research and Development

By R. C. SUTCLIFFE, Ph.D.

The request comes to me for an article in a trilogy "looking ahead", a task congenial enough, offering scope for imagination, for an expression of opinion not to be tested against the facts so quickly as were many forecasts one has made, and not calling for the exacting scholarship which a historical survey would demand. Yet it is difficult for one who is only the second holder of a post styled "deputy director for research" to resist a glance backwards.

Research, that is organized and planned research, with scientists recruited within an approved establishment and devoting their efforts to a programme of investigations by much the same sort of arrangement as another group of men may run a factory, is so widely practised today that the newcomer from the university may not realize that it is almost a creation of the present generation, and among the most significant of social changes. "Creation" is not quite correct, "rapid growth" would be better, for there have been distinguished research bodies in existence outside the universities for a much longer period. But when many present members of the staff were looking round for a career they will recall that a life that could be devoted in large measure to research was hardly to be found outside university appointments. And even the universities provided little more than an environment in which personal research might flower protected from economic winds, freely without forcing, yielding the useful and the useless indifferently so that it be but satisfying intellectually. We were not so much different in outlook from the Greeks as is sometimes implied, technical advance lay largely with businesses and engineers, illiterate folk with soiled hands of no account to a philosopher.

In the new scientific phase of social evolution the Meteorological Office might well have been a noteworthy pioneer and to some extent it was; for research needed no specific mention as the pursuit of scientists when the Office was young, and the few scientists who joined the staff took their place quite naturally as men of learning.

As happens not uncommonly in other families, distraction came with a new generation. Weather forecasting, a weakly infant at one time almost despaired of, suddenly with World War I began to develop prodigiously, and for some 30 years was like the cuckoo in the nest affording no one time to think of much else. So the Meteorological Office did tend to lose its pronounced research character to recover it again only when social trends overtook it with World War II. There was no cuckoo, only a troublesome but legitimate child, still awkward

but less all-demanding in maturity, and showing distinct signs of yielding to the influence of his gentler sister research now she has come into her birthright.

When one now contemplates the future part research will play in the Office one must not only respond to the general climate of social philosophy which urges us on to material progress whatever moral philosophy may teach, we must also take a domestic view and realize our special responsibilities.

Practical professional meteorology, meteorology as a useful science, is almost a monopoly of the Office in our country. This is not due to any political bias against private enterprise, if there is such bias it is irrelevant, but simply due to the fact that business other than state business is as yet too scattered and too thinly spread to afford a profitable private harvest. We are, after all, a small profession. If we show our worth we shall no doubt expand in numbers, but at present the whole profession comprises less than 200 scientific staff and some 1,000 "experimental officers". If all these were recruited from the universities and had each a professional life of some 40 years, the average annual intake would be no more than 30, perhaps half a dozen research scientists and a score or more of other graduates. Such numbers could not unreasonably be produced by one university department; our professional demands on the universities are in numbers quite small.

This sort of arithmetic does not take us far with the research outlook, but it is material. For if the universities have limited scope for preparing meteorologists their provisions for meteorological research must at least be affected. The Office is accordingly left with a major responsibility not only for service but also for research and we must provide accordingly.

Another of the facts of life, welcome or not, is that research today is the field for the expert. The unique characteristic of this scientific and technological age is that progress by research is everywhere being forced by organization and directed effort instead of being left to advance in leisurely fashion. It has become almost a race, and anyone whose attention is largely devoted to other matters will in a few years fall so far behind as to be almost out of the future running, unless his genius allows him to start a new line of his own. This is significant for the future of the Office in that it hardly seems possible to envisage an effective organization where individuals are interchangeable and may move from research to general service and then back to research again as promotions and other factors throw up vacancies in the structure. Such an arrangement cannot possibly produce first-rank research scientists, and it is questionable whether it will produce first-rank forecasters or administrators either. Unhurried, voluntary, spare-time research is a fine tonic to the general practitioner or the administrator with a taste in that direction, but a preoccupation with research and an eye always on a future return to full-time activity is not calculated to call forth the full effort on public service and efficient management which these things equally demand.

In some way or another we must therefore look for a system which will allow the research scientist to continue indefinitely on research work in his bent. A drift from research to wider human activity seems to be natural, acceptable and beneficent but it is necessarily almost a one-way transition.

Looking now to the field of research which is open to us we must recognize that we are only just beginning to clear a little space, as it were with our two hands, to allow more elaborate tools to come into play. Meteorology, except in

some special little corners, has for long been a science calling for little more than enthusiasm, painstaking work, common sense and a modest scientific training; until of late the applications of advanced skills either experimental or theoretical have been a rarity. Climatology has consisted of the collection of data and their processing by elementary statistical and cartographical methods; investigations on the synoptic scale, the basis of weather forecasting, have been analytical and cartographical, calling for no recondite technique which could not be acquired by practice granted moderate physical knowledge. Smaller-scale studies, the scale of turbulence, have led to the specialist theory of impressive practical utility, but even here the inspiration lay in the pioneering ideas rather than in abstruse analysis or refined experimentation. Cloud and precipitation physics have made little progress although the deep subtleties were gradually becoming recognized, while instrumentation throughout meteorology called rather for the technical skill of the mechanic than for any out-of-the-way specialist training.

All this has been changed, much during the last decade. The climatologist has not only begun to adapt more rigorous concepts from the specialist science of statistics, but, with the advent of much upper air information, is able to think on physical quantitative lines towards theories of climate and of the general circulation of the atmosphere. In time we shall doubtless be able to describe in coherent fashion the significant three-dimensional behaviour of the atmosphere, of climatic change and of seasonal anomalies, we shall be able to test quantitatively any theory which is propounded and shall know, if not how to predict these changes and anomalies, at least why the practical prediction problem defeats us; we shall certainly in time "understand".

Synoptic meteorology is rapidly becoming a coherent branch of hydrodynamics built up on orthodox lines from the basic physical equations and forecasting is taking on the characteristics of an exact science. Again we can see the road being cleared towards an intellectually satisfying understanding of the problems, and subjective estimates or flair must lose ground continuously to calculation and to statistical judgments. Synoptic and forecasting research has entered an exciting phase and the Meteorological Office is in the heart of the battle.

The basic physical problems of radiation, turbulence and condensation must yield to measurement and analysis until rival theories and speculations give way to established textbook presentations of the subject. While we cannot easily see how every unique event in meteorological history, the individual shower, an occurrence of fog, of stratocumulus cloud, of night frost or pollution concentration, for example, will be analysable or calculable, for we cannot envisage observational techniques to provide the complete specifications of the individual problems, yet we can expect to understand, to know quantitatively what processes are involved, and to know what detail in the meteorological complex is within our practical powers of analysis; our theoretical powers must surely lead towards a satisfying comprehension.

To a very large extent this opening up of the problems to theoretical attack is the result of practical techniques of observation and experiment, and the meteorologist must now go along with physicists and engineers in the elaboration of electronic and other techniques of measurement. The radio-sonde, radar methods, modulated and pulsed-light searchlights for cloud heights and for studying very high levels of the atmosphere, self-recording aircraft instruments, the use of rockets, the ozone spectrophotometer, tracer substances as agents for

the study of diffusion, measurements of radio-activity and chemical analyses of the atmosphere, these are but indications of technical developments requiring high specialist skill and knowledge; the experimental meteorologist must have his eyes continually open for new ideas, and for possible applications of ideas emerging in other fields where the general meteorologist cannot hope to keep abreast.

With our science rather suddenly gaining new vitality and opening up refreshing prospects it is hardly the time to point to its limitations, but, recalling that we are being carried along in the new current of technological progress whose explicit aim is the modification and control of nature for the material welfare of mankind, we might rather humbly admit that so far we play a subservient part. Our advice is sought in many and varied practical ways, but we are the handmaidens of aeronautics, of agriculture and many other technologies and have no unrestricted technology of our own. Ahead of the physicist, the chemist, the biologist or the sociologist there are evidently unlimited realms of "engineering", of creating new materials, new processes, new organisms, new organizations. Ahead of the meteorologist lies the understanding of meteorological phenomena, but will not this field tend to be worked out until it yields only more detailed knowledge at the price of much effort, knowledge affording intellectual satisfaction to the few and of little practical utility? Is pure meteorology to be tidied up, put away in textbooks and merely brought out for re-editing as basic theories evolve, or is it to found a line of technological control of nature rivalling atomic physics or engineering chemistry in economic terms? Of this prospect there are indeed signs.

Setting aside the control of very local climate in human and other shelters as barely meteorology, and recognizing such things as wind and frost protection for agriculture as minor interference with nature, we must look to the control of weather and climate on the large scale. I shall make no facile attempt to predict how this may come about, by planned irrigation, by interference with cloud and condensation processes, by modification to the radiation balance through the control of albedo, by controlling evaporation from the oceans through surface films, by triggering off large-scale dynamical changes at critical phases as some speculators have envisaged. We may have our opinions about the ultimate feasibility of such methods, but it would be foolish to dispose of all of them and all other similar notions as entirely pipe dreams.

Whether or not such a future lies ahead, and whether or not we find the prospect alluring if it does, there is no doubt whatever that meteorology is now a developing science, set on a long road of progress and should be able to attract, challenge and satisfy the most exacting scientific intellects which the country can produce. It seems likely that the Meteorological Office will continue to provide the facilities and the sustenance for much of this effort and they must be the best within our reach.

All is not yet perfect but there is much to afford us pride. Our forecasting research group, recently strengthened, has few rivals in the world. Our new division for climatological research is perhaps unique of its kind and its worldwide studies are welcomed everywhere. Our Meteorological Research Flight provides facilities for direct investigations wherever aircraft can reach, on a scale unequalled in any other single institution. Our efficient and closely knit instrument-development group are pioneering continuously and can hold their own in any circle.

I think we can justly claim that we have within our Office a tolerably well balanced research organization of healthy size, perhaps a little too sparing here and there but with effective punch behind its attack. I look to the future to see essential parts brought physically together in a new Office where mind can strike on mind, where new ideas will fertilize each other. I look for flexibility in organization, permitting the productive research worker to continue his specialist activity not broken unnecessarily by promotions and postings. Our recruitment is excellent, it must become superlatively so by affording the material prospects and, above all, the scientific facilities and freedom which alone can contain the urgent spirit of the true man of science.

If we can in justice say that our research organization is now as vital a body as any of its kind anywhere in the world, we must keep it so by planning gently, restricting our passion to control by taking a balanced view of what is or may be utilitarian, by fostering the wild growth and not too soon marking it down as a weed. I do not think we have much cause for fear.

Finally we may think of our relations with the outside world of science and affairs. Other parts of our Office are eager to develop their usefulness to the community, and they must be backed up by applied research. We must co-operate with and support work in the universities with which, especially through the Meteorological Research Committee and the activities of the learned societies, we have and must maintain the happiest relations. And we must keep in step with the growing internationalism of science by visits abroad, by entertaining visitors from other countries and by making our voices heard wherever scientists are gathered together.

I look to see research work in the Office regarded as an enviable career for the chosen, advancing knowledge towards rich humanitarian ends. It is an attractive future.

Services for Aviation and Defence

By A. C. BEST, D.Sc.

The title to this note distinguishes between aviation and defence, but in fact the present-day concept of the defence of most countries includes active participation by military aircraft. The meteorological services for such aircraft are basically similar to those for civil aircraft, though there are differences in the emphasis placed upon the various types of service. There are, however, a few aspects of defence which are not related to aviation, and we shall refer to these at the end.

It is a fact familiar to most forecasters that an attempt to foresee the future sequence of events is sometimes facilitated by examination of the sequence in the near past which has led up to the present moment. So in an attempt to foresee the nature of the meteorological requirements of the aviation of the future, it may be profitable to consider how the changing pattern of aviation during the past few decades has modified the meteorological needs. Unless we expect some fundamental change in the basic concept of an aircraft, the future services for aviation will need to include all those which are supplied today, together with additional services dictated by the operation of more advanced types.

The earliest aircraft were mechanically unreliable, their ceiling was low and their range short, and navigation was largely a matter of comparing a map with

the country flown over. Since those days the aeroplane has been improved enormously as a piece of engineering. Navigational aids allow the whole flight to take place above the clouds, and the range of a modern aircraft almost removes the possibility of running out of fuel, provided pay load is suitably limited. Many of the earlier hazards have thus disappeared. Their disappearance has emphasized the remaining hazard of the weather. The development of the metorological-forecast services for aviation has continuously operated to diminish the weather hazard, but has been continuously countered by the completely justifiable wish of the operator to fly, for economic or military reasons, in worse and worse weather. With this pattern behind us, we may expect that the task of the aviation meteorologist of the future will be even more exacting than it is today, until such time as blind landing is fully effective. Commercial competition in the world of civil aviation and tactical reasons where military aircraft are concerned, will together ensure that new devices or procedures for safe flight are also directed to facilitating flight in weather conditions which today would cause postponement.

There is an urgent reason why the meteorologist should endeavour to foresee the future aviation pattern. Aircraft are designed to serve specific purposes, to operate at specific heights, speeds and ranges. The designer needs to know what meteorological conditions will be encountered by the aircraft in normal operation. Generally his need is for meteorological statistics relating to the aspects of weather which will affect the operation of aircraft in use several years hence. But the statistics themselves take a long time to collect if they refer to some variable which is not currently being observed, so that 10 years or so would not be an unduly long time between starting to observe a new meteorological variable and the routine operation of a new-type aircraft affected by that variable. This is particularly true when new air routes are under consideration. In recent years there have been a few transpolar flights. We must expect that such flights will become increasingly frequent in the future, and the meteorologist will be called upon to supply first climatological statistics (for both the surface and the upper air) and later operational forecasts for these little-known areas.

Turning now to the detailed changes which have occurred during the past few decades and which have directly affected the meteorologist, it is convenient to group them under,

(i) Take-off and landing (including ascent to and descent from operating height)

(ii) Flight at operating height.

With regard to the first group, take-off and landing speeds have increased significantly. By itself this would imply the need for higher minimum cloud base and better visibility for landing, but this need has been more than cancelled by the development of approach aids and runway marking. The result is that aircraft are now able to land with a lower cloud base or poorer visibility than was possible previously. The higher landing speeds have nevertheless involved longer runways, and it may well be that this factor will restrict any further increase in landing speeds. Approach aids, however, are likely to improve so that we may expect future aircraft to be able to land at a fully equipped airport in worse conditions than are at present acceptable. Naturally it is in marginal conditions that the greatest accuracy in forecasting is required. Unfortunately the marginal conditions for landing aircraft today are already within the range

in which casual variations, both with space and time, are significant. Forecasts of cloud height and visibility must always quote, or imply, a range within which the value will lie. It may well be that the accuracy of forecasting these two variables will improve in the future, but it seems much less likely that we shall be able to be more precise about cloud height and visibility at a given time and place in conditions which are marginal for landing. This is because the range is now largely governed by the residual casual variations which seem quite unpredictable. If this is true there is likely to be an increasing demand for accurate measurements nearer and nearer to the time and place which are critical for an aircraft attempting to land. This, however, is not a complete solution. Aircraft of today—and probably still less those of the future—cannot afford to use a lot of fuel circling an airfield at low level awaiting an opportunity to land. If diversion to another airfield is to be made, the pilot needs to know if possible while still at operational height. There may thus be a requirement in the future for short-period aerodrome forecasts (an hour or two in advance) of cloud height and visibility, the forecasts to give maximum and minimum values.

Temperature at airfield level is important for take-off purposes. For example, in limiting conditions, with the Comet 1 an increase of 1°C. in the ambient temperature decreases the lift to such an extent that the load must be lightened by one passenger. With the present trend in aircraft design it seems that this factor may become of greater importance.

It has always been true that for very short flights, a pilot has tended to rely upon the latest actual weather report from the destination aerodrome. This habit has arisen because the weather changes in a short time are unlikely to be greater than the errors in the forecast based upon a synoptic chart constructed from observations made several hours previously. In this context a "short" flight means one lasting a short time, and even today it is possible for an aircraft to leave London and reach Rome before a synoptic chart based upon observations made at the moment of leaving has been drawn in the forecast office. With the increasing speed of aircraft there is a need to reduce the present interval between the making of observations and the completion of the corresponding synoptic chart. It may be that further developments in facsimile transmission will assist in a solution of this problem.

The meteorological information supplied to facilitate the in-flight operation of aircraft may be conveniently grouped under two headings. There is the information which is designed to assist navigation; this consists primarily of upper winds and, in more recent years, upper air temperatures. The second group deals with the factors which directly affect safety or comfort, and may be said generally to deal with dangerous phenomena. With very few exceptions, aircraft are used as means of transport; the cargo may consist of passengers, freight, bombs, guns and ammunition or other commodities, and all these can be grouped under the title "pay load". The fuel required for a long flight represents a considerable fraction of the total weight lifted, and any increase in the fuel required must be compensated by a decrease in the pay load. The operator usually requires to know several hours before the flight starts what fuel will be required in order that he may plan his pay load. On long trips (e.g. Atlantic crossings) it is sometimes possible to plan a course which, though longer than the shortest crossing, uses less fuel because the headwind component is less. Flight planning such as this is a comparatively recent development, and we may expect it to assume greater importance as the length of non-stop flights increases.

The problem becomes increasingly difficult as the operating height of aircraft increases, owing to the difficulty of constructing satisfactory contour charts for the higher levels. To some extent this difficulty arises from the fact that errors in heights computed from the ordinary radio-sonde ascents are cumulative. Other techniques for forecasting the winds at high levels are being explored. This poses the instrumental problem of providing a method of making upper air soundings to great heights regularly and at a cost which is not prohibitive. The importance of this navigational information has been underlined in recent years by aircraft encountering jet streams.

There is a close connexion between the importance of winds for navigational purposes and the forecasting of landing conditions. Because landing forecasts are not 100 per cent. accurate, an aircraft must carry sufficient fuel to permit diversion to one or more alternate airfields in the event of the primary destination being unfit for landing. This extra fuel is carried at the expense of pay load, and there is an urgent need to reduce this economic handicap.

Turning now to the information which we have classed as "dangerous phenomena", it is interesting to note that the situation is almost continually fluctuating. The vertical currents associated with thunderstorms have always been potentially dangerous. Investigations in recent years have led to the view that the danger can be minimized by appropriate action on the part of the pilot. On the other hand the increased speed of aircraft has increased the risk if it should be caught, unexpectedly, in such conditions. In the early days of aviation, ice accretion was not particularly important because aircraft seldom operated in such conditions. With improved aircraft and instruments, flying in such conditions became more frequent and the meteorologist was called on to forecast the areas where it might occur. More recently the larger aircraft have been equipped to deal with ice accretion, but this in turn involves the weight penalty associated with the equipment. Aircraft of the future may operate at heights where icing is unknown—but they must ascend to this level and, later, descend. Similarly with clear-air turbulence. In the earliest days, it was not encountered. Then for a period it was encountered, but was of no great significance. Now it is recognized as important from the point of view of the passengers' comfort or of the bomb aimer. Each advance in aviation technique is likely to be accompanied by its own meteorological problems. The meteorologist cannot always forecast the significance of meteorological phenomena to aircraft of the future (e.g. how many meteorologists would guess that the size of airborne dust particles may be important in engine design?), but he can make every effort to study the region of the atmosphere in which aircraft of the future will fly in order that he can give the best advice when problems do arise.

So far, we have assumed that aircraft of the future will be of the present conventional type. Nevertheless, there is obviously a probability that vertical-lift aircraft or helicopters may be in common use in the future and it may be profitable to speculate on what, if any, differences this will make to the meteorological services required. If such aircraft could land and take off from airfields of the present type it is probable that the requirements with regard to cloud height and visibility would be much less stringent than at present. Past developments in aviation, however, suggest that, for economic reasons, such aircraft may be required to operate from very confined spaces. The vertical speed, even of present-day helicopters, is very low when landing. This must make them susceptible to the effects of wind gustiness, and this phenomenon is

notoriously accentuated in the neighbourhood of buildings. It is likely then that for aircraft of this type landing on a small landing ground, the pilot will need to see his landing point from a height of a few hundred feet in order to take the action necessary to counter the gusts. The marginal weather conditions may thus approximate to those for present-day aircraft landing on a conventional airfield. More generally, it seems likely that the pilots of helicopters of the future will need more detailed knowledge of the structure of the lowest few hundred feet of the atmosphere than is included in present-day aviation forecasts.

It is improbable that the rotating-wing type of aircraft will ever travel as high or as fast as the fixed-wing aircraft. Owing to this the wind at operational height may be more important than it is with the faster fixed-wing aircraft of today.

Pilotless aircraft flying at great heights and great speeds is another new type with which we may be confronted in the distant future. It is perhaps unlikely that such aircraft will carry passengers—the aircraft in fact may be the descendants of the V.2 rocket. From our present point of view such aircraft—or perhaps missiles is a more appropriate word—may be divided into three convenient categories. The first category comprises those over which there is no control after leaving the launching ramp. The meteorological problems for these will be similar to those for conventional artillery, but the vertex of the trajectory may be substantially higher. The second category comprises missiles which have incorporated within themselves some device for maintaining a prescribed course. Meteorologically these do not seem to pose any additional problems. The third category comprises what are generally known as guided missiles. For such missiles, the guiding inevitably implies control by radio waves, and this introduces a new meteorological problem. Radio waves suffer attenuation during passage even through cloud-free atmosphere. If clouds are present, the attenuation is increased both by absorption and scattering. It may be that in the future there will be a need to forecast the physical characteristics of cloud in this connexion.

To some extent this new commitment is already bringing some compensation in that radar is already in use as a means of observing clouds from the ground. For short-period forecasting for a particular locality this use may well increase.

We have introduced the subject of guided missiles as an extension of the aviation question, but this brings us to considerations of "defence" other than in connexion with aviation. The use of radio waves seems to be increasing rapidly in various defence projects, and since the travel of such waves can be greatly influenced both by the liquid or frozen water suspended in the atmosphere and by the temperature and humidity structure of the atmosphere in the vertical we may expect that there will be an increasing demand for forecasts of such factors. It is unlikely, however, that the use of guided missiles will render conventional artillery obsolete and the need for artillery meteors will remain.

A meteorological problem of defence which is not related directly to aviation concerns the distribution of debris from an atomic explosion. The writer does not know to what height the explosions from present-day atomic bombs may reach, but it seems likely that, in the future, such explosions may reach a height between 100,000 and 200,000 ft. The travel of the debris will then be partly governed by winds at such heights. Whether or not such bombs are ever used, the meteorologist must expect to be questioned about the probable wind there. We may hope that this will never be more important than an academic exercise.

Forecasting and Public Services

By S. P. PETERS, B.Sc.

Many people imagine the Meteorological Office to be a Department occupied almost exclusively with telling the general public, through the medium of the British Broadcasting Corporation and the Press, whether wet or dry, warm or cold, weather is to be expected during the ensuing 24 hours. Before the First World War 1914–18 this quite restricted responsibility in the matter of weather forecasting did very largely obtain, apart from the supply of information to shipping, but then, as now, there were numerous other scientific activities in which the Meteorological Office was engaged. In the realm of forecasting, however, the passage of the years has been accompanied by ever-growing demands on the Office, and these have represented not only a substantial broadening of the field of application of weather forecasting, but also a very marked increase in the severity of those demands. In this connexion the following extract from the Annual Report of the Meteorological Committee for the year ended March 31, 1915 is significant:—

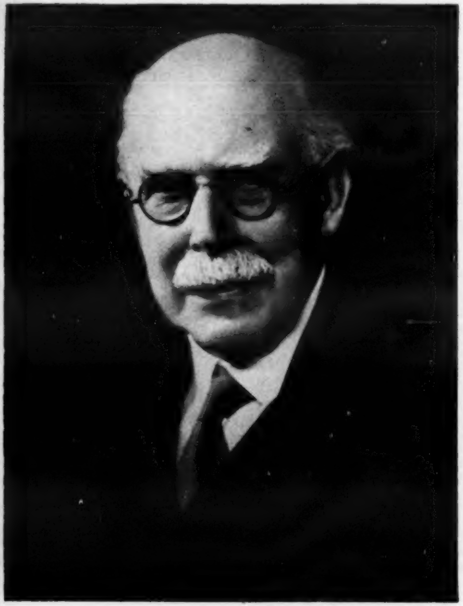
> Up to the middle of November* there were prolonged periods of quiet, anticyclonic weather during which forecasting was exceptionally easy, while from the middle of November onward there was a very wet boisterous period. Depression followed depression in what may be called normal sequence for weeks on end, and the preparation of forecasts for periods not exceeding 24 hours presented no great difficulty.

Today the detailed information required by various sections of the community to be included in forecasts, and the necessity for advising the probable times of occurrence of particular features of the weather, render outmoded any statement of complacency such as the above. "Quiet anticyclonic weather" can provide forecasters with as much anxiety in regard to the formation or dispersal of fog or of a cloud sheet as "a very wet boisterous period" can do in timing the onset, duration and character of rain, or the arrival of clearing weather associated with a cold front, all of which phenomena are matters of vital concern, directly or indirectly, to some section of the public.

With the rapid development of aviation during the war years 1915–18 a burden of work and responsibility was placed on the forecasting department which was quite unprecedented. To the extent that this was effectively assumed and discharged, competence was acquired to enable a wider and more detailed service to be given to the community in general after the war, and also to civil aviation during the critical early years of its development. In particular, a service of harvest forecasts consisting of notifications to subscribers of the onset of spells of settled weather was inaugurated in the summer of 1919, whilst the supply of forecasts to the B.B.C. for broadcasting with the evening news bulletin began in November 1922.

During the years that followed, and up to the outbreak of the Second World War 1939–45, a slow but steady advance was made in providing forecasting services to meet specialized requirements. After the serious Thames floods which occurred in January 1928, a warning service was introduced by which the Meteorological Office notified certain authorities when weather conditions appeared likely to cause unusually high tides in the Thames. By about the year 1933 the value of forecasts in connexion with pigeon racing had come to be recognized by the organizations controlling long-distance pigeon flights, and the practice became established of obtaining forecasts to minimize the risk of

* From the outbreak of war in August.



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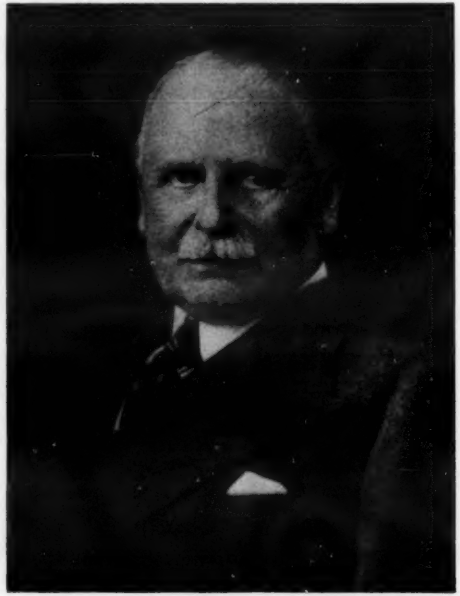
SIR NAPIER SHAW, F.R.S.,
DIRECTOR OF THE METEOROLOGICAL OFFICE
1900–20
AND SCIENTIFIC ADVISER TO H.M. GOVERNMENT
ON METEOROLOGY 1918–19



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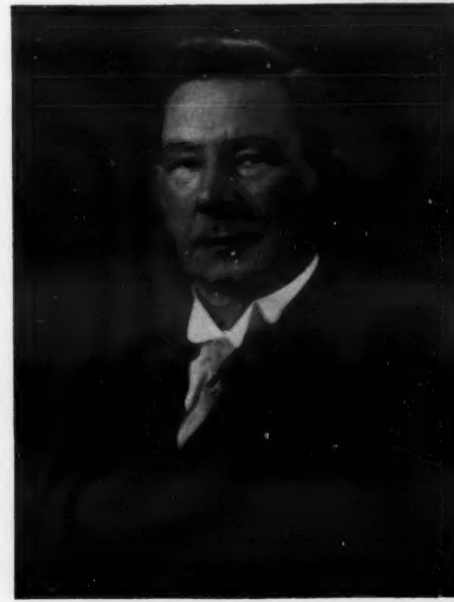
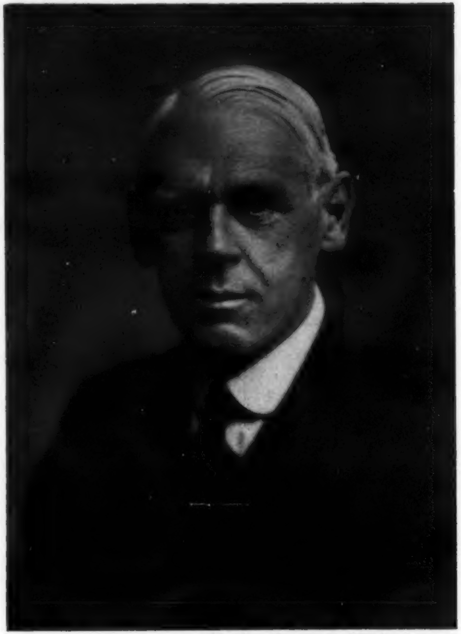
COLONEL SIR HENRY LYONS, F.R.S.,
ACTING DIRECTOR OF THE METEOROLOGICAL OFFICE
1918–19



SIR GEORGE SIMPSON, K.C.B., C.B.E. F.R.S.,
DIRECTOR OF THE METEOROLOGICAL OFFICE
1920–38

[*To face p. 192*

To face p. 193]



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SIR NELSON JOHNSON, K.C.B., D.Sc.,
DIRECTOR OF THE METEOROLOGICAL OFFICE
1938–53

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SIR GRAHAM SUTTON, C.B.E., F.R.S.,
DIRECTOR OF THE METEOROLOGICAL OFFICE
1953–

valuable birds being lost through encountering unfavourable winds and weather. The introduction during April and May 1936 of special forecasts of frost, for the benefit of horticulturists, is recorded in the Director's Report for that year. From the same Report is taken the following historical reference to forecasts by television:—

> An experiment was made between November 2 and 28 of issuing weather charts by the television process and accompanying them by a spoken description of the chart and a short forecast. This experiment was made at the Alexandra Park television station of the British Broadcasting Corporation, and as the radius of the transmission is limited the forecast referred to London only. The experiments indicated that there were possibilities in this method which might have to be reviewed later when television becomes one of the amenities in the lives of the majority of the inhabitants of the country.

At the outbreak of war in 1939 current weather information was immediately placed on the secret list, and all forecasting services for the benefit of the public at large were suspended, but very little time elapsed after VE day before the restitution of most of these services was called for, and gradually achieved.

That very many activities of daily life are dependent on, and influenced by, the weather is a platitude, and although agricultural and marine activities receive the special attention of forecasters, there are numerous other interests which the Meteorological Office endeavours to help. In the forefront of its means of reaching those who would employ its services the B.B.C. continues to be found, and every effort is made to exploit to the full both the sound and television programmes as media for informing the general public. With the discontinuance in 1950 of the AIRMET broadcasts, a service which was inaugurated several years before the war and revived in January 1946, a valuable channel of communication was lost, and the passage of time, together with the success of the personal presentation of forecasts on the television service, has only served to underline the advantages of a talk by forecasters on the weather situation over a bulletin supplied by the Meteorological Office and read by an announcer. It is much to be hoped that, in collaboration with the B.B.C., the return of forecasters to the microphone will be achieved by the Meteorological Office during its centenary year.

The days are gone when newspapers can be regarded as primary vehicles for supplying the public with the most up-to-date forecasts. It is manifest that the bulletins broadcast on the B.B.C. Home Service in the early morning, which are based on the 0000 and 0300 G.M.T. charts, must supersede those appearing in the morning newspapers, which are based on the previous 1200 and 1500 G.M.T. charts in summer, and on the 1500 and 1800 G.M.T. charts in winter. There is little that can be done about this, and it can happen, and it sometimes does, that the morning B.B.C. and newspaper forecasts are divergent. The Press could, however, perform a useful service for meteorologically minded readers by printing a weather chart showing either the actual synoptic situation at a particular hour, 12 or 18 hr. earlier, or a forecast chart. In view of the errors which may occur in a chart constructed to represent the situation expected 24 hr. ahead it would be preferable for "actual" and "forecast" charts to be printed alongside each other, but if space is available for one chart only there is a good deal to be said for this being an "actual" rather than a "forecast" chart. In order to give forecasts for the various parts of the United Kingdom conveniently, the country is divided into 26 districts. Each comprises a number of counties, selected to form a group which can be described by a geographical name that is reasonably self-explanatory and can also be said to have some claim to being a climatological unit. There is inevitably a certain arbitrariness about

the grouping, but the serious reader will of course take steps to find out to what district the place in which he is interested belongs. The grouping was revised and improved in 1954, but the most satisfactory arrangements may not yet have been made, at least in so far as Scotland is concerned.

The influence of various aspects of the weather on all forms of transport needs no emphasis. The stimulus given to forecasting by the advent of flight has already been alluded to, and the history of aviation forecasting is outside the scope of this article. The crippling effects on ground transport which may result from such weather hazards as snow, ice and fog can, however, be considerably minimized by the dissemination of suitable warnings.

In addition to including snow warnings in bulletins for broadcast by the B.B.C. the Meteorological Office provides special subscription services of snow forecasts, one of which is designed for the use of municipal authorities responsible for snow clearance, whilst another is for the benefit of skiers in Scotland. To electrified railways, the deposition of ice (and snow) on conductor rails and cables is a matter of concern, since such deposits can readily act as insulators and bring electric trains to a standstill. A warning service has consequently been in operation for about six years, which provides for controllers of electrified sections of railway, chiefly those of London Transport and the Southern Section of British Railways, being advised each afternoon when conditions are expected which will be favourable for the occurrence of rail or cable icing in specified areas during the ensuing night. The receipt of such advice enables the authorities to take steps to counteract the ice, by such means as the running of special trains which spray oil over conductor rails or the switching into operation of oil baths, inserted into those rails, from which oil is automatically sprayed over the rail by passing trains.

The fog hazard is one which can be said, in general, to affect all forms of transport equally, and here again subscribers to the special warning service receive notification of the fog prospects. After the "smog" of December 1952 arrangements were made to provide the B.B.C. with special warnings for broadcast with the routine weather bulletins whenever fog is expected to persist for at least 24 hr. in stated areas of the country. Industrial and domestic users of coal are then expected to reduce to a minimum their contributions of smoke to the pollution of the atmosphere.

Knowledge of the general level of temperature to be expected is of particular value to electricity and gas companies in the anticipation of demands, and temperature forecasts are accordingly supplied daily to units of the British Electricity Authority in various parts of the country, and gas companies are advised whenever significantly colder weather is in prospect. Frost warnings for substantial areas of the country are passed to the B.B.C. for broadcasting with the routine forecast bulletins, whilst the expectation of frost in a specific place can be notified to registered subscribers.

Sudden changes of humidity are of particular concern to manufacturers of confectionery, and certain of these avail themselves of a special forecasting service which gives warning of the arrival of air of high humidity, particularly following a cold spell, with the attendant probability of heavy condensation on cold surfaces.

Sudden and substantial decreases of atmospheric pressure are closely related to the efflux of gas in mines, and warnings of rapid falls of pressure are supplied to certain collieries.

Earlier passing reference has been made to the forecasting services which the Meteorological Office provides for mariners and agriculturists. For the benefit of the former there are the well known shipping bulletins and gale warnings which are supplied to, and broadcast by, the B.B.C., and in addition, broadcasts are made by wireless telegraphy concerning the weather situation over the Atlantic. Indeed, the bulletins issued by various means for the benefit of shipping around the British Isles and in the eastern and central parts of the North Atlantic are as comprehensive as anywhere in the world. The accuracy of many of the forecasts which are included in these bulletins is considerably dependent on the number and distribution of ship reports available to the forecaster. The North Atlantic ocean weather stations render particularly useful service in this connexion, but there remains a constant need for reports from a large number of merchant ships to enable reasonably accurate synoptic charts of the weather to be constructed.

The requirements of the farmer, the market gardener, and the small holder in regard to the weather to be expected are met to a considerable degree in the B.B.C. bulletins. The forecasters at the Central Forecasting Office at Dunstable are kept informed, through the medium of the Agricultural Branch of the Meteorological Office, of the current agricultural and horticultural activities in different parts of the country and the related weather factors of special importance, and cognizance is taken of these in the preparation of the forecast bulletins. However, in regard to factors which are subject to considerable local variations, such as frost and wind, and for very short-period forecasts, the best and most detailed service is to be obtained by telephone from one of the forecasting offices listed in the "Post Office Guide" and elsewhere. Whilst there is probably no section of the community which does not stand to reap some benefit from any advances made towards extending the period for which reasonably reliable forecasts can be given, it is doubtless the grower who, by and large, would be the most advantaged.

The problem of forecasting for several days ahead has been under continuous study in the Meteorological Office in recent years, with particular reference to the upper air circulation over a large area of the northern hemisphere, and trials have shown that some measure of success can be achieved in forecasting the general character of the weather and temperature over the British Isles up to 3 days ahead. On the other hand, attempts to forecast details of the weather and temperature at individual places on individual days beyond 24 hours have not been altogether encouraging.

Reliable assessment of the accuracy of period forecasts, or indeed of any forecasts, is beset with difficulties, and any figure of percentage accuracy, or terse statement that the forecasts are "seldom right" or "seldom wrong", should be treated with extreme reserve, until it is known exactly how the assessments were reached. In view of the fact that, by reason of the recognized limitations of forecasting, official forecasters act in the capacity of advisers rather than prophets, it is essential that by the phraseology they employ they should indicate as far as possible the degree of probability of the occurrence forecast, or the confidence with which the forecast is endowed. However, the use of such phraseology complicates the subsequent verification of the forecast and introduces an element of subjectivity into the checking. The problem of forecast verification is, nevertheless, receiving continuous attention in its various aspects.

What should be said of the future in regard to forecasting? Are there grounds for optimism? In so far as the attainment of greater accuracy by the employment of conventional and current methods is concerned, realism requires it to be recognized that progress during the past decade has been slow, and that notwithstanding the steady prosecution of research the rate of progress during the next decade seems unlikely to be substantially greater, at any rate so far as can be seen at the present time. It would, however, be wrong to infer that the value of the forecasting service to the community will not go on increasing, since, apart from an extension of services in spheres of human activity wherein they are already established, there are additional spheres in which forecasts of various meteorological elements can well be employed and be of a useful standard of accuracy in the existing state of knowledge. The important thing is to get potential users, particularly in industry and commerce, to realize how the forecasting service can help them in their special problems, and for the meteorologist to assist them in framing their application for service in the manner best calculated to secure the most efficient results. As regards the effect on forecasting of the use of electronic computers, it is too early to express any definite opinion, since the employment of such computers in numerical forecasting is at present only in the research stage. There are, however, some grounds for supposing that, so far as obtaining forecast charts for 24 hours ahead is concerned, the electronic computer will prove to be a valuable aid, and its adoption in forecasting a very significant milestone in the history of synoptic meteorology.

THE METEOROLOGICAL OFFICE AND THE INTERNATIONAL ORGANIZATION

By E. GOLD, D.S.O., F.R.S.

Meteorology today rests on international foundations. These have been laid by combined effort but the Meteorological Office has contributed in high degree to their solidity. There were meetings and exchanges before the Office was constituted, notably the Conference in Brussels in August 1853, concerned primarily with ocean meteorology, out of which the Meteorological Office may be said to have been born—a sea nymph.

For the next 20 years Europe was in a disturbed state—the Crimean War; the German wars against Austria, Denmark and France—and it was not until 1873 that the first general International Meteorological Congress was held at Vienna, for which there had been preliminary discussion a year earlier at an informal meeting in Leipzig (August 1872). This Vienna Congress stands out almost as the founder of international meteorology. Early in July 1873 the Foreign Office notified the Board of Trade that Her Majesty's Government had decided to nominate Mr. R. H. Scott, Director of the Meteorological Office, and Mr. Alexander Buchan, Secretary of the Scottish Meteorological Society and, later, a member of the Meteorological Council, as "delegates to represent this country at the Meteorological Congress to be held at Vienna in September next", and three weeks later the Board of Trade sent the two delegates instructions for their guidance "You should attend at the Conference as a deliberative assembly and impart and glean such information as you may be able. I am however to observe that you should abstain from pledging Her Majesty's Government in any way". The Army Medical Department asked Scott if he would be willing to represent them and also if he thought a separate representative would be better. Scott said yes to both questions, but the Department

decided on Scott and expressed, more spaciously and graciously, "the Director General's gratification at being afforded the opportunity of confiding the interests of the Army Medical Department to such safe and able hands and, in the event of proposals involving expense being made, of securing the assistance of so sound a judgment in selecting for support such only as are necessary for the *bona fide* furtherance of science".

So Scott and Buchan went to Vienna, and on their return reported very briefly to H.M. Government that the Congress took no decisions involving expenditure.

But this Congress under the Presidency of Buys Ballot took many decisions which have governed meteorological practice since, and may be found in the two standard textbooks, the "Codex of Resolutions adopted at International Meetings 1872–1907" by H. H. Hildebrandsson and G. Hellmann and the "Répertoire des Résolutions de l'Organisation Météorologique Internationale", by E. Van Everdingen which covered the period up to 1939 and was published in 1943.

The principal recommendations at Vienna specified (*a*) the units of time to be used, namely the mean solar day of the place of observation ending at midnight, the calendar month, and the civil year, and Dove's 73 5-day periods for means of temperature; (*b*) suitable combinations of hours for observations, e.g. 7, 13, 21 or 9, 15, 21; (*c*) the weather symbols, essential in the absence of an international language, for the representation of "hydrometeors"; (*d*) the specification of wind direction "the English designations should be used generally: N = North, E = East, S = South, W = West"; (*e*) the definitions of meteorological stations, Central Office, Central Station, Stations of the First, Second and Third Orders. The most important decision was the establishment of a Permanent Committee of seven members to act between Congresses, which met every five or six years. R. H. Scott was Secretary of this Committee from its first meeting in Vienna on September 16, 1873 until the meeting in St. Petersburg in 1899, which he could not attend owing to the sudden death of the, then, Marine Superintendent of the Office, Nav. Lt C. W. Baillie, R.N. H. H. Hildebrandsson succeeded Scott as Secretary.

One of the first actions of the Permanent Committee was to agree upon a code for the exchange of telegraphic reports—a code of 5-figure groups because each such group was charged as one word. There were two primary groups BBBDD FFWTT for barometer, wind, weather and temperature and two supplementary groups T'T'RRR MMmmS for wet-bulb temperature, rain, maximum and minimum temperatures and state of the sea. This was the British form; the Continent had three figures for temperature, and only one for wind force and two for rainfall. The Beaufort scale was adopted for wind force for observation at sea "with the addition of the amount of sail which Beaufort's ship would have carried had she been rigged with double topsails". Another important action was the specification of the form of register to be used at sea, largely the work of Capt. H. Toynbee, and the corresponding specifications of the forms for the publication of daily observations and monthly summaries for land stations.

Subsequent Meetings and Conferences refined and added to the recommendations of the Vienna Congress. [It should be emphasized that there were no compulsory decisions; the recommendations, to be effective, had to be agreed with substantial unanimity.] Naturally as the leading maritime nation Great Britain took a prominent part in all matters of marine meteorology. But

the British representatives were always ready to assist in getting the best use made of good proposals put forward by other maritime nations—an example is their agreeing in 1876 that Great Britain should take 50 sets of "Hoffmeyer's" synoptic charts covering Europe and the North Atlantic. Of other countries, Austria took 40, Russia 30 and the rest, numbers varying from 1 to 15—total 205. At the meeting at Paris in 1900, Sir Napier Shaw was elected a member of the Committee, and from 1907 to 1923, the year of the Conference at Utrecht, he was its President, bringing to that Office both the optimism of his predecessor, M. Mascart, expressed in the *mot* "the greatest and most terrifying difficulties are those which do not really exist" and his own administrative and scientific ability. These resulted in a comprehensive statement of the constitution and functions of the International Meteorological Organization, the revision of the telegraphic code, the publication of an English edition of the "Codex of Resolutions", and the re-establishment of the Organization as an effective instrument of international meteorological collaboration after the disruption caused by the First World War.

Among the major changes in the last 35 years have been the complete revision of the codes for international exchange, by telegraph and wireless, of reports of surface observations, largely on the basis of British proposals put forward as a result of experience during the war of 1914–18; agreement on codes for upper air reports; the establishment of a comprehensive decimal classification of meteorological literature, a most valuable and notable step forward for which Dr. C. E. P. Brooks was in large measure responsible.

The first comprehensive publication of the details of the issues by wireless telegraphy in different countries of the collective reports of observations was prepared by M. A. Giblett, who lost his life in the disaster to the Airship R101. These issues between the world wars formed the basis of forecasting and of what is generally understood by "synoptic meteorology". The publication mentioned was the prototype of the International Publication, No. 9, issued after the establishment of a Permanent Salaried Secretariat of the International Meteorological Organization. Sir George Simpson played an important part in bringing to birth this embryo of its full grown successor in the World Meteorological Organization. It was also Sir George Simpson's work on the Beaufort Scale of wind force which enabled international agreement to be finally reached on a scale of equivalent speeds, at the meetings at Zurich and Vienna in 1926. Diversity between the Continental and British equivalents had been long a source of contention, impossible of reconcilement, but when Dr. Hesselberg said briefly and emphatically "Simpson's proposal is good" the matter was clinched. Notable also was Mr. E. G. Bilham's success in securing the revision of the specifications, largely on the lines of the British proposals, at Paris in 1946 and his fight, gallant though unsuccessful, at Toronto in 1947 for the logical and practical scale of visibility. Sir Nelson Johnson's work, as President of the International Meteorological Organization from its re-establishment in 1946 until his retirement in 1953, in securing agreement at Washington in 1947 on the Convention establishing the World Meteorological Organization may well be described as putting the coping stone on the contribution of the Meteorological Office to the International Meteorological Organization. When the Washington Conference was on the point of breaking down, "it was", said the Chief of the United States Weather Bureau, "the deliberate and skilful guidance of the President" which brought them through all obstacles.

WEATHER OF APRIL 1955

The highest mean pressure of the month in the Atlantic sector was again over the British Isles (Kew had the highest figure 1023 mb. and the greatest anomaly +10 mb.). This expressed recurrence of blocking situations, chiefly between the 12th and the 25th. Continuity between the anticyclones of March and April over the eastern North Atlantic was broken by two sequences of depressions and fronts travelling east in late March and again after April 2, though pressure was generally above normal over France and Biscay during these intervals. The lowest mean pressure in April was 999 mb. off south-east Greenland near 35°W., an anomaly of −10 mb. which apparently represents deeper depressions than usual with little or no position anomaly. There were few remarkable features in the pressure pattern elsewhere in the hemisphere, although pressure seems to have been below normal over much of the polar basin and the usual spring anticyclones over the Canadian archipelago gave a pressure maximum farther south than usual over Baffin Land with a positive anomaly +6 to +8 mb.

Temperatures were a little above normal over most of western Europe and generally below normal farther east—the greatest anomalies were +5°C. at Spitzbergen, and −4°C. in south-west Finland and Greece.

In the British Isles a mild westerly air stream predominated during the first ten days and the last week of the month; during the remainder, the weather was anticyclonic with drought conditions affecting a large part of the country.

A centre of high pressure gave a fine sunny day on the 1st, but the following day an active trough to a depression near Iceland crossed the country accompanied by widespread rain. On the 3rd an influx of milder air into the south-west was marked by locally heavy rain, but there were good sunny periods in the north, though with scattered thunderstorms. During the next three days a mild south-westerly air stream predominated, while minor troughs crossed the country giving occasional, mainly slight, rain alternating with sunny periods. Temperatures were above average and exceeded 60°F. in places. The moister air gave rise to hill and coast fog in the south-west, patches of fog in the English Channel and Irish Sea, and an increase in early morning fog elsewhere. Still warmer air spread from the south-west on the 7th as fronts associated with a deep Icelandic depression crossed the British Isles with widespread rain, heavy in places particularly in Scotland, where among the heavier falls in 24 hr. that day were 2·60 in. at Polnish Lochailort, 2·24 in. at Arisaig House, both in Inverness-shire and 2·06 in. at Aros, Isle of Mull. But on the 9th an anticyclone off our south-west coasts increased in intensity, and in consequence rain accompanying the passage of a trough of low pressure across the country that day was only slight in the south. The anticyclone began to move north-eastwards on the 11th, became centred over the British Isles by the 14th and thereafter persisted in the neighbourhood till the 20th. During this period the weather was dry, sunny and mild by day, but ground frost occurred most nights; it was the warmest Easter Monday at many places on the south coast for six years, and on the 14th sunshine totals exceeding 12 hr. were reported from a number of places throughout the country. As the anticyclone drifted slowly westward on the 21st slightly cooler air spread southwards over the eastern side of the country; the grass minimum temperature fell to 20°F. at Kew during the early hours of the 20th and 22nd and snow showers were reported from Lerwick on the 21st and 24th. The anticyclone began to collapse on the 23rd, and thereafter a return to a westerly type gradually brought to an end the drought which had developed over much of England, though rainfall amounts in the south-east were small. There was widespread rain, heavy locally in the west, associated with the passage of an active trough across the country on the 27th when more than 3 in. of rain was recorded at Blaenau Festiniog, Merionethshire. An influx of air from France resulted in the highest temperatures of the year so far on the 29th; several places in Kent recorded 77°F. With a total rainfall for the month of 0·15 in. Shoeburyness reported the driest April since records began in 1920. Rainfall was more than average in places in the extreme west, but over much of Great Britain there was less than 75 per cent. Over the greater part of south-east England less than 25 per cent. was recorded with as little as 12 per cent. from Felixstowe and Edenbridge.

The general character of the weather is shown by the following provisional figures:—

	AIR TEMPERATURE			RAINFALL		SUNSHINE
	Highest	Lowest	Difference from average daily mean	Percentage of average	No. of days difference from average	Percentage of average
	°F.	°F.	°F.	%		%
England and Wales ...	77	21	+1·8	65	−4	111
Scotland	74	20	+2·8	76	−3	124
Northern Ireland ...	65	23	+2·8	103	−2	121

RAINFALL OF APRIL 1955

Great Britain and Northern Ireland

County	Station	In.	Per cent. of Av.	County	Station	In.	Per cent. of Av.
London	Camden Square ...	·43	28	*Glam.*	Cardiff, Penylan ...	2·04	82
Kent	Dover ...	·21	13	*Pemb.*	Tenby ...	2·75	120
"	Edenbridge, Falconhurst	·23	12	*Radnor*	Tyrmynydd ...	3·38	92
Sussex	Compton, Compton Ho.	·65	33	*Mont.*	Lake Vyrnwy ...	3·18	100
"	Worthing, Beach Ho. Pk.	·21	13	*Mer.*	Blaenau Festiniog ...	10·27	166
Hants.	St. Catherine's L'thouse	·57	31	"	Aberdovey ...	3·50	135
"	Southampton (East Pk.)	·36	19	*Carn.*	Llandudno ...	·95	56
"	South Farnborough ...	·21	14	*Angl.*	Llanerchymedd ...	2·50	113
Herts.	Harpenden, Rothamsted	·44	27	*I. Man*	Douglas, Borough Cem.	3·13	126
Bucks.	Slough, Upton ...	·34	24	*Wigtown*	Newton Stewart ...	3·11	122
Oxford	Oxford, Radcliffe ...	·65	59	*Dumf.*	Dumfries, Crichton R.I.	1·41	60
N'hants.	Wellingboro' Swanspool	·69	46	"	Eskdalemuir Obsy. ...	2·51	74
Essex	Southend, W. W. ...	·19	15	*Roxb.*	Crailing... ...	·76	47
"	Felixstowe ...	·14	12	*Peebles*	Stobo Castle ...	·78	37
Suffolk	Lowestoft Sec. School ...	·38	26	*Berwick*	Marchmont House ...	·64	32
"	Bury St. Ed., Westley H.	·38	25	*E. Loth.*	North Berwick Gas Wks.	·85	62
Norfolk	Sandringham Ho. Gdns.	·97	64	*Midl'n.*	Edinburgh, Blackf'd. H.	·44	30
Wilts.	Aldbourne ...	·52	27	*Lanark*	Hamilton W. W., T'nhill	1·13	60
Dorset	Creech Grange... ...	1·02	47	*Ayr*	Colmonell, Knockdolian	2·78	110
"	Beaminster, East St. ...	1·25	53	"	Glen Afton, Ayr San. ...	2·66	89
Devon	Teignmouth, Den Gdns.	·96	48	*Renfrew*	Greenock, Prospect Hill	3·76	109
"	Ilfracombe ...	2·95	141	*Bute*	Rothesay, Ardencraig ...	4·87	163
"	Princetown ...	4·14	82	*Argyll*	Morven, Drimnin ...	4·75	190
Cornwall	Bude, School House ...	1·57	83	"	Poltalloch ...	5·08	168
"	Penzance ...	1·53	63	"	Inveraray Castle ...	6·08	132
"	St. Austell ...	1·59	56	"	Islay, Eallabus	3·33	116
"	Scilly, Tresco Abbey ...	1·31	67	"	Tiree	2·87	117
Somerset	Taunton ...	·90	51	*Kinross*	Loch Leven Sluice ...	1·23	64
Glos.	Cirencester ...	1·01	54	*Fife*	Leuchars Airfield ...	·64	40
Salop	Church Stretton ...	1·60	73	*Perth*	Loch Dhu	4·85	101
"	Shrewsbury, Monkmore	1·19	80	"	Crieff, Strathearn Hyd.	1·53	70
Worcs.	Malvern, Free Library...	·95	53	"	Pitlochry, Fincastle ...	1·23	55
Warwick	Birmingham, Edgbaston	1·10	57	*Angus*	Montrose, Sunnyside ...	·64	35
Leics.	Thornton Reservoir ...	1·11	65	*Aberd.*	Braemar	·82	35
Lincs.	Boston, Skirbeck ...	1·44	107	"	Dyce, Craibstone ...	·77	37
"	Skegness, Marine Gdns.	1·31	98	"	New Deer School House	1·08	54
Notts.	Mansfield, Carr Bank ...	1·07	62	*Moray*	Gordon Castle	1·34	77
Derby	Buxton, Terrace Slopes	2·88	98	*Nairn*	Nairn, Achareidh ...	1·07	70
Ches.	Bidston Observatory ...	1·52	93	*Inverness*	Loch Ness, Garthbeg ...	·94	41
"	Manchester, Ringway...	1·87	104	"	Glenquoich	6·28	97
Lancs.	Stonyhurst College ...	3·22	119	"	Fort William, Teviot ...	4·42	98
"	Squires Gate ...	1·50	84	"	Skye, Broadford ...	5·60	124
Yorks.	Wakefield, Clarence Pk.	·51	30	"	Skye, Duntuilm ...	2·95	91
"	Hull, Pearson Park ...	·61	39	*R. & C.*	Tain, Mayfield... ...	·94	51
"	Felixkirk, Mt. St. John...	1·51	90	"	Inverbroom, Glackour...	2·38	64
"	York Museum	1·10	69	"	Achnashellach	5·17	97
"	Scarborough	1·00	64	*Suth.*	Lochinver, Bank Ho. ...	2·27	80
"	Middlesbrough... ...	·90	66	*Caith.*	Wick Airfield	1·32	66
"	Baldersdale, Hury Res.	·88	40	*Shetland*	Lerwick Observatory ...	2·98	130
Norl'd.	Newcastle, Leazes Pk....	·67	42	*Ferm.*	Crom Castle	2·61	102
"	Bellingham, High Green	·84	34	*Armagh*	Armagh Observatory ...	2·75	131
"	Lilburn Tower Gdns. ...	·49	25	*Down*	Seaforde	2·19	84
Cumb.	Geltsdale	2·23	105	*Antrim*	Aldergrove Airfield ...	2·61	124
"	Keswick, High Hill ...	1·99	65	"	Ballymena, Harryville...	2·42	92
"	Ravenglass, The Grove	2·94	119	*L'derry*	Garvagh, Moneydig ...	2·39	98
Mon.	A'gavenny, Plâs Derwen	1·03	37	"	Londonderry, Creggan	2·34	91
Glam.	Ystalyfera, Wern House	5·84	154	*Tyrone*	Omagh, Edenfel ...	...	...

Printed in Great Britain under the authority of Her Majesty's Stationery Office
By Geo. Gibbons Ltd., Leicester

Wt-34. K16.